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Surgical Approaches for Minimally Invasive Interlocking Nail Osteosynthesis in Dogs

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Abstract

Objective The aim of this article was to describe, in detail, the safe portals and surgical approaches for minimally invasive interlocking nail osteosynthesis.

Methods Fifteen dog cadavers weighing between 30 and 40 kg were used, 10 for an anatomical study and 5 for creation of the minimally invasive interlocking nail osteosynthesis portals. Anatomical dissections were used to establish landmarks and precise anatomical interrelationships of the surgical approaches for the minimally invasive use of interlocking nails in the tibia, femur, and humerus. Subsequent dissection was made to evaluate potential iatrogenic lesions.

Results The reference points for, and anatomical interrelationships of, the minimally invasive surgical approaches to the tibial, femur, and humerus diaphyses were detailed. No damage to any important neurovascular structures was observed in any cadaver.

Conclusion Safe portals for approaching the humerus, femur, and tibia were described in detail to allow safe application of interlocking nails in a minimally invasive fashion.

Keywords
- biological osteosynthesis
- canine
- fracture
- safe corridors

Introduction

The concept of minimally invasive osteosynthesis is based on the preservation of the primary fracture hematoma as well as the blood supply and integrity of the soft tissues adjacent to the fracture. Thus, internal and external osteosynthesis techniques have been developed to give prolonged stable fixation and to allow indirect fracture reduction for realignment of the bone and limb.[1] These techniques produce better outcomes with faster bone healing, as well as reduce surgical time and complication rates.[2–4]

Minimally invasive plate osteosynthesis (MIPO) was first described in human medicine but is widely performed in veterinary orthopaedics. A number of studies evaluating MIPO, primarily in dogs, have been published in recent years. The portals and adjacent anatomical structures are well described and experienced veterinary surgeons can perform the technique in all long bones of small animals, that is, the humerus, radius, femur, and tibia.[1,5–7]

Interlocking nails (ILN) are widely used for management of long bone fractures in humans and are being increasingly used in veterinary surgery.[8–10] These nails offer the advantage of placement that requires minimal soft-tissue dissection and they can be applied using minimally invasive techniques. In addition, ILN have excellent mechanical properties and provide fracture resistance to all forces acting upon a fracture repair. However, minimally invasive interlocking nail osteosynthesis (MINO) is technically challenging and requires a steeper learning curve compared with open surgical approaches and inexperience can result in longer operating times.[11]

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Detailed knowledge of normal anatomy is mandatory if minimally invasive surgery is to be performed safely and effectively. However, no detailed descriptions of the surgical approaches for veterinary MINO application have been published to date. The aim of this study was to describe the surgical approach for MINO techniques in dogs, detailing the safe portals and important anatomical landmarks.

Methods

The study was divided into two parts. First, anatomical dissections were performed on 10 dog cadavers, weighing 30 to 40 kg, representing a number of different breeds. Dissection was performed in both forelimbs and hindlimbs to establish landmarks and precise anatomical interrelationships for surgical approaches for the minimally invasive application of ILN in the tibia, femur, and humerus. Subsequently, another five dog cadavers were used to create and describe the portals for MINO with subsequent dissection to evaluate iatrogenic lesions. The study was carried out with the consent of the ethics committee in the use of animals and was approved under protocol number 3771/20.

All animals included in the study died or were euthanatized for reasons unrelated to this study. The cadavers were cooled to 8°C and dissected within 24 hours of death.

MINO portals were created in the humerus, femur, and tibia by two veterinary surgeons with experience in fracture repair. The pelvic and thoracic limbs of each animal were used to perform lateral, medial, and craniolateral approaches in the femur, tibia, and humerus, respectively. Subsequently, an anatomical dissection was performed on all the limbs to identify iatrogenic injuries that may have been caused by the approaches and to record individual anatomical structures. The approaches described in this study were all based on reports of minimally invasive techniques in the literature,[1,7,8,10,12] comparative dissection of dogs, and the authors' experience.

Results

Humerus

A craniolateral approach was used for the humerus. The dog was positioned in lateral recumbency with the target limb upward. When fluoroscopy is available, the supine position may be preferred for this approach.[10]

The greater tubercle was used as the main landmark for starting the proximal portal approach. A 2- to 4-cm-long skin incision was created immediately proximal to the greater tubercle and extended to the acromial head of the deltoid muscle. Skin and subcutaneous tissue were retracted and an incision was made in the superficial fascia to expose the greater tubercle between the acromial head of the deltoid muscle and the cleidobrachialis muscle. These structures were be handled carefully to preserve the axillobrachial vein located caudal to the incision, and the cephalic vein running below the cleidobrachialis muscle. The medullary canal of the humerus was drilled in a normograde fashion (►**Fig. 1**), using intramedullary pins or a drill similar in thickness to the applied nail and with the drill directed slightly caudomedially to follow the medullary canal.

The main landmark distally is the lateral epicondyle of the humerus. A 2- to 4-cm incision was made, extending cranioproximally from the lateral epicondyle, to expose the distal metaphysis of the humerus. After subcutaneous dissection, the brachiocephalicus muscle was identified, and an incision was made in the deep fascia to allow the cranial

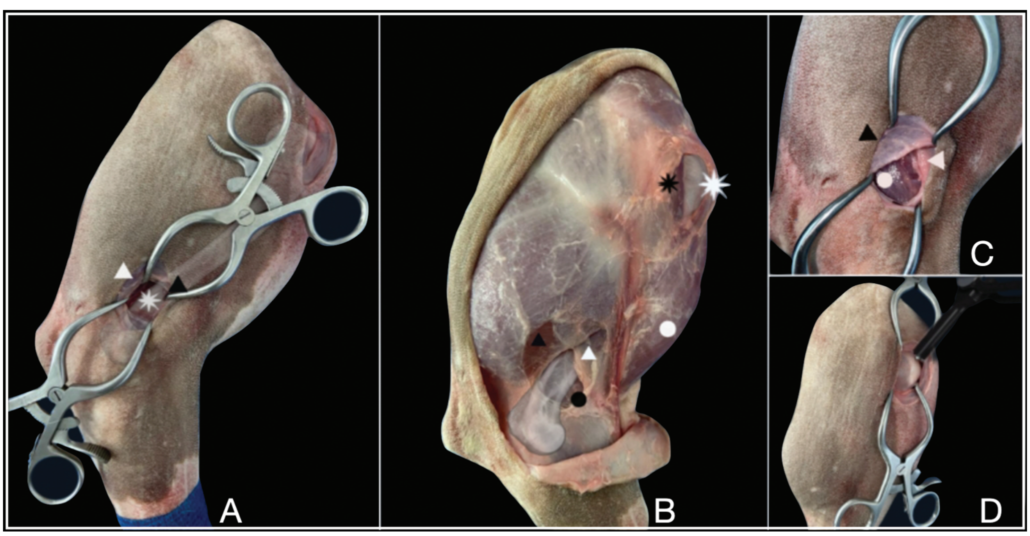

Fig. 1 Schematic anatomical representation of the craniolateral portals for minimally invasive interlocking nail osteosynthesis in the humerus. (**A**) Proximal portal: skin incision and visualization of the cleidobrachialis muscle, cranial to the greater tubercle; distal portal: retraction of the lateral head of the triceps brachii muscle (*white arrowhead*) and the brachialis muscle (*black arrowhead*), allowing visualization of the distal metaphysis of the humerus (*white asterisk*). (**B**) Main structures in the craniolateral approach of the humerus: acromial head of the deltoid muscle (*black asterisk*), cleidobrachialis muscle (*white asterisk*); between them, the greater tubercle; biceps brachii muscle (*white point*); brachialis muscle (*white arrowhead*), lateral head of the triceps (*black arrowhead*), and extensor carpi radialis muscle (*black point*). (**C**) Distal portal: visualization of the lateral head of the triceps brachii muscle (*black arrowhead*); more ventrally is the extensor carpi radialis muscle (*black point*), and cranially, brachialis (*white arrowhead*). (**D**) Exposure of the greater tubercle and an example of the perforation site for approaching the medullary canal of the humerus, after retraction of the acromial portion of the deltoid muscle.

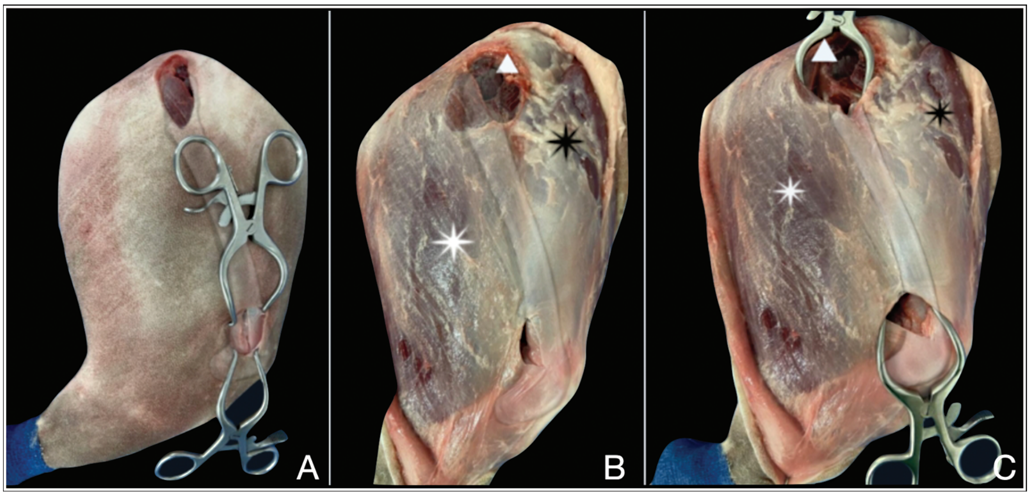

Fig. 2 Schematic anatomical representation of the lateral approach to the femur for performing the minimally invasive interlocking nail osteosynthesis technique. (**A**) Proximal and distal portals for implantation of interlocking nail after incision of the skin and subcutaneous tissue. (**B**) Anatomical specimen dissected after portal creation. The tensor fasciae latae is located cranial to the femur (*black asterisk*). The biceps femoris (*white asterisk*) is caudal to the femur; middle gluteal muscle (*white arrowhead*) is located dorsal to the greater trochanter. (**C**) Proximal and distal bone metaphyses, and the structures mentioned in (**B**), after using Gelpi retractors.

retraction of the brachiocephalicus muscle. This retraction allowed visualization of the radial nerve, a critical structure to be avoided during surgery. Cranial retraction of the brachialis muscle protected the branches of the radial nerve (►**Fig. 1C**) and permitted safe visualization of the distal diaphysis. If further exposure of the metaphysis was required, the extensor carpi radialis muscle was partially elevated to facilitate application of bone forceps or the distal bolts of the ILN. Bone forceps can be used to reduce and manipulate bone fragments. However, extreme care was required if they were placed at the distal metaphysis, to avoid damage to the radial nerve.

Femur

For this approach, the dog was positioned in lateral recumbency with the target limb upward. The proximal portal was created through a skin incision approximately 2 to 4 cm in length, beginning 1 to 2 cm proximal to the greater trochanter and extending distally (►**Fig. 2A**). After subcutaneous dissection, an incision in the fascia lata, at the cranial edge of the biceps femoris muscle, was made. Caudally, the superficial gluteal is overlain by the biceps femoris muscle and caudal retraction of the biceps femoris allowed visualization of the greater trochanter and its muscular insertions (►**Figs. 2** and **3**). To penetrate the medullary canal and insert the ILN, a drill sleeve was used and dissection between the middle gluteal muscles and biceps femoris allowed access to the intertrochanteric fossa. Alternatively, access was gained between the fibers of the middle gluteal muscle (►**Fig. 3B**). Finally, the vastus lateralis muscle was exposed. It lies distal to the superficial gluteal muscle and has its insertion on the lateral face of the greater trochanter (►**Fig. 3A**).

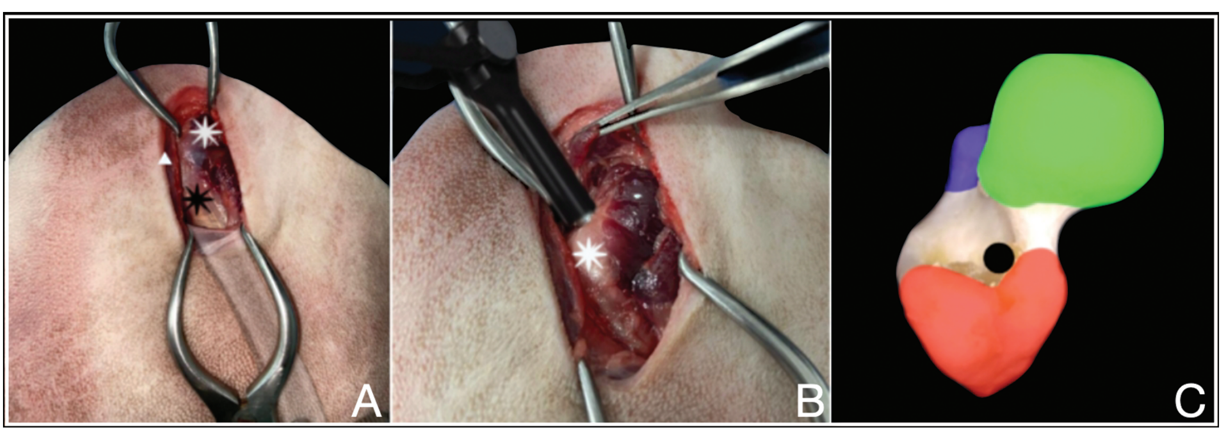

Fig. 3 Schematic anatomical representation of the proximal approach to the femur and perforation site for the introduction of the interlocking nail. (**A**) Proximal incision allowing the identification of the middle gluteal (*white asterisk*) and vastus lateralis muscles (*black asterisk*) insertion into the greater trochanter; biceps femoris retracted caudally by Gelpi forceps (*white arrowhead*). (**B**) Visualization of the greater trochanter (*white asterisk*). After exposing the superficial gluteal and middle gluteal, it is possible to approach the trochanteric fossa, allowing penetration of the medullary canal. (**C**) Dorsal view of the femur. Note the interlocking nail insertion site in the trochanteric fossa in *black*. Illustration of the greater trochanter in *red*. Third trochanter in the lilac. Femoral head and neck in *green*.

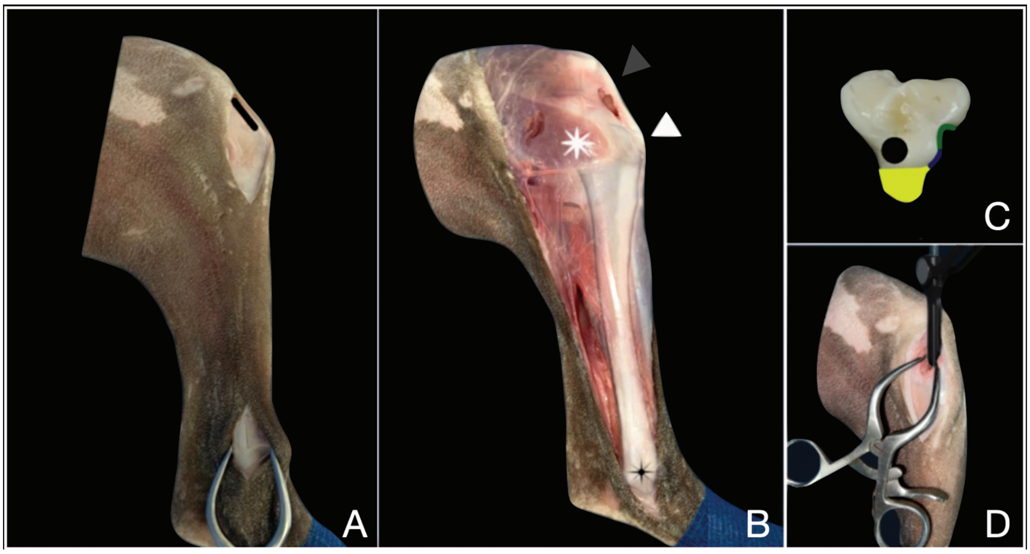

Fig. 4 Anatomical representation of the medial approach to the tibia for minimally invasive interlocking nail osteosynthesis technique. (**A**) Proximal portal: skin and fascia incision, identification of the incision site, and approach to the stifle joint (*black line*). Distal portal: visualization of the distal tibial metaphysis after skin and subcutaneous incision. (**B**) Visualization of the main anatomical structures in the medial approach to the tibia. In the proximal approach, the main structures are the patella (*gray arrowhead*), patellar ligament, tibial tuberosity (*white arrowhead*), and caudal part of the sartorius muscle (*white asterisk*). Incision point of the joint capsule for perforation and implantation of interlocking nail (between *gray and white arrowheads*). Distal portal: identification of the medial malleolus, which was used as a landmark for the first incision (*black asterisk*). (**C**) Demonstration of the point for penetration of the tibial medullary canal (*black point*), immediately caudomedial to the tibial crest (*yellow*). (**D**) Representation of the site of introduction of the nail.

The patella, lateral epicondyle, and supracondylar tuberosity are important landmarks for creating the distal portal. A 2- to 3-cm-long skin incision was made, starting at the lateral supracondylar tuberosity of the femur and extending laterally to the level of the base of the patella. Dissection of the subcutaneous tissue was followed by an incision in the fascia lata along the cranial border of the biceps femoris muscle (►**Fig. 2A,B**). The distal femur was exposed by retraction of the biceps femoris muscle caudally and the vastus lateralis muscle cranially. Stifle exposure was needed in the distal portal to facilitate alignment of the femur (►**Fig. 2C**).

Tibia

The tibia is accessed by a medial approach. Indications for this approach include diaphyseal and metaphyseal fractures. The dog was positioned in dorsal recumbency, allowing movements of the limb in multiple planes and a full range of motion of the stifle. First, a medial skin incision was made from the middle third of the patellar ligament extending distally to the tibial crest (►**Fig. 4A**). The patellar ligament was identified and the fat pad retracted caudolaterally. Then a medial parapatellar mini-incision was made to access the drilling site for access to the tibial medullary cavity. A drill sleeve must be used to ensure the correct depth of the drill hole and to protect the soft tissues (►**Fig. 4B**). The hole is drilled just cranial to the intermeniscal ligament, in a normograde fashion, with the drill directed slightly caudally to follow the medullary canal (►**Fig. 4C,D**). Following insertion of the ILN in the medullary canal, a small dissection of the proximal fascia was necessary to allow the preparation of the holes and the application of the locking bolts. Partial elevation of the caudal part of the sartorius muscle allowed exposure of the proximal tibial shaft, if necessary.

In the distal tibia, a medial skin incision was made proximal to the medial malleolus and extended from distal to proximal. The subcutaneous tissue was incised to expose the bone surface of the distal tibia. Care is needed to avoid the cranial branches of the saphenous vein (►**Fig. 4A**).

Discussion

Despite the potential advantages of minimally invasive osteosyntheses, there is still resistance to these techniques from veterinary surgeons, since they can be challenging and have a long learning curve.[11] Performing minimally invasive techniques requires a detailed knowledge of surgical anatomy and a comfort with limited visualization of the anatomical structures.[13] Surgeons must know the exact location of the anatomical structures to create portals with low risk of complications and acceptable surgical times.

Studies providing detailed description of surgical approaches for minimally invasive techniques are highly relevant in orthopaedic surgeries.[13] Although the MIPO portals have been described in detail[1,5–7] and are similar to the MINO portals, some key differences can be highlighted. In the MINO portals, the drilling sleeves direct the exact location and trajectory of the holes and, therefore, minimal dissection is necessary for the implantation of the screws, unlike the MIPO, which, because it is necessary to adjust the plate in the center of the bone and visualize the holes to implant the screws, requires further periosteal and soft-tissue dissection. In addition, in MIPO it is essential to create a periosteal tunnel,[5] which, despite being made with noncutting instruments, causes damage to the periosteum's vascularization.

Previous studies reported the clinical application of ILN using minimally invasive approaches.[10,14] In this study, we focus on a detailed description of the anatomical structures and schematic demonstration of safe corridors providing a detailed guide for the surgeon. The great challenge in creating MINO approaches is the perfect exposure of the insertion points of the nail and bolts without damage to the adjacent structures.

In the humerus, the proximal portal is used to expose the greater tubercle. In this approach, elevation of the scapular portion of the deltoid muscle must be avoided, whereas retraction can provide adequate visualization of the proximal humeral metaphysis for the insertion of bolts or screws. No injuries were observed in the orobranchial and circumflex humeral arteries. The risk of injury to the cephalic vein is very low due to its cranial position relative to this approach. Lesions to the radial nerve and cephalic vein were not observed in this study.[15]

In the proximal approach to the femur, the incision must be started above the greater trochanter to allow the insertion of the ILN and the jig through the trochanteric fossa. Access to the medullary cavity can be facilitated by partial elevation of the superficial gluteal muscle and retraction of the middle gluteal muscle. Another option is the dissection between muscle fibers; however, this maneuver is associated with higher morbidity and damage to muscles can occur. When the proximal portal is created, the greater trochanter is exposed without damage to the biceps femoris and vastus lateralis, although partial elevation of the vastus lateralis muscle might be necessary to facilitate bolt/screw insertion. Without this exposure, the proximal bolts would have limited anchorage and are likely to exit in the trochanteric fossa, especially in well-muscled dogs. In the distal portal, lesions of the caudal branches of the femoral artery are common, but these should be preserved to improve local blood supply.[12] To enable this, a slight retraction between the distal muscles of the lateral side of the femur is necessary. In this study, we found that damage to these arteries and veins occurred if visibility was restricted. In addition, lateral stifle arthrotomy is always necessary to ensure proper rotational alignment of the femur. If fluoroscopy is not available, the surgeon must always open the stifle joint to check the correct alignment of the femur.[12]

Minimally invasive osteosynthesis is commonly performed in the tibia of dogs and cats. The limited soft tissue surrounding the tibia means that closed reduction of tibial shaft fractures is easier than in other bones.[16] However, the canine tibia has a sigmoidal shape, which makes the positioning of the nail more challenging in some cases.[8] During the proximal approach to the tibia, a medial parapatellar incision is necessary, which makes this a more invasive technique with increased risk of injury to the patellar ligament and cranial cruciate ligament.[17] To avoid this, lateral retraction of the patellar ligament and use of a drill sleeve are recommended. Additionally, elevation of the caudal portion of the sartorius muscle is not necessary to expose the proximal metaphysis, although partial elevation can be necessary for bolt fixation in some cases.[1] No injuries to the medial saphenous vein occurred during creation of the distal portal. This is probably because the vein runs ventral to the correct portal tract.

Conclusion

In this study, the MINO approaches were described in detail, and an illustrative guide for approaching the humeral, femoral, and tibial diaphysis was produced based on anatomical studies. The caudal femoral artery branches were the only vessels damaged in any approach. It is important to understand that there will be anatomical differences between dogs and thus portals may need to be adapted for some individuals. The main limitation of this study is that it is potentially easier to create access portals on cadavers without fractures than on real patients. Further studies in clinical fracture cases are needed to validate the clinical relevance of this research.

Author Contributions

L.D.V.F., M.B.W., D.L.G.G.G., and N.J.A.G. made substantive scientific and intellectual contributions to the study. L.D. V.F., M.B.W., and N.J.A.G. contributed to the conception and design of the study. L.D.V.F., M.B.W., N.J.A.G., F.D.R.C., and D.L.G.G.G. were responsible for the technical procedures. L.D.V.F., M.B.W., N.J.A.G., F.D.R.C., and D.L.G.G.G. contributed to data analysis and interpretation, writing of the manuscript, critical review, and final approval of the manuscript.

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None.

Conflict of Interest

None declared.

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