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Distal Normograde Intramedullary Pin and Locking Plate Placement in the Canine Humerus: A Cadaveric Study

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Abstract

Objective

To identify a repeatable anatomic landmark for pin insertion and to describe the technique for placement of a distal normograde intramedullary (IM) pin of approximately 35% of the IM diameter using this approach combined with a locking compression plate (LCP) on the medial aspect of the canine humerus.

Study Design

Ex vivo anatomic study.

Sample Population

Canine cadavers (n=10 Greyhounds).

Methods

An anatomic landmark for pin insertion was identified based on three-dimensional reconstructions of previous elbow computed tomography studies and cadaveric dissection of the medial aspect of the

humeral condyle. Bilateral distal normograde IM pin and LCP placement were performed and confirmed radiographically and by disarticulation and sagittal sectioning.

Results

The anatomic landmark for pin insertion was consistently identified in each specimen using the technique described. Distal normograde insertion of a 3.5 mm IM pin was possible in Greyhound cadaveric humeri at the described location in conjunction with a 3.5 mm LCP with fixed angle, locked screws. A monocortical locking screw was required to avoid interference with the IM pin in 28 of 60 of the 3 proximal screw holes. No pin interference was encountered in any of the distal screw holes.

Conclusion

The anatomic landmark and technique described in our study enabled repeatable successful placement of a distal normograde IM pin of approximately 35% of the IM diameter combined with an LCP on the medial aspect of the canine humerus. This technique may be useful for locking plate-rod fixation of distal humeral diaphyseal fractures.

The largest published case series of humeral fractures in companion animals found 47% involved the distal diaphysis and over half of these were comminuted.[1] Several repair techniques have been reported for humeral fractures including intramedullary (IM) pins with or without cerclage,[2] external skeletal fixation,[3] interlocking nails,[4, 5] and unilateral or bilateral bone plates.[6-8] Of 130 humeral fractures, 30% were repaired with a construct that included an IM pin.[1]

Plate-rod constructs have also been reported for humeral fracture repair.[1, 9] Advantages over a bone plate alone include simplifying fracture reduction, maintaining spatial alignment, reducing plate strain across the fracture gap, and increasing the stiffness, load to failure, and fatigue life of the construct.[10-12] Current general recommendations for plate-rod constructs recommend the use of a pin that occupies 30–40% of the narrowest IM diameter.[10, 12]

Fractures of the distal humeral diaphysis require an IM pin to completely engage the medial aspect of the humeral condyle.[13-16] A recent study of distal normograde IM pinning of the humerus concluded that a pin occupying 36–45% of the IM diameter should be used based on a medullary measurement at the distal 80th percentile of humeral length.[16] This study defined a successful pin insertion point as starting on the medial epicondyle and avoiding the articular cartilage of the humeral trochlea.[16]

Another study describing normograde and retrograde IM pin placement into the distal humerus through the medial epicondyle defined an insertion point based on the successful exit points of pins from the retrograde component of the study.[17] The majority of these pins exited on the nonarticular surface of the medial aspect of the humeral condyle distal to the medial epicondyle. However, there was significant variability in these exit points and the study did not identify a consistent starting point to facilitate repeatable pin insertion.[17] The authors proposed that final pin position caudal to the medial epicondyle may facilitate the placement of other implants to augment fracture repair; however, concurrent plate application was not performed as part of that study.

The objectives of our study were to identify a repeatable anatomic landmark for pin insertion and to describe the technique for successful placement of a distal normograde IM pin of 35% of IM diameter using this approach combined with a locking compression plate (LCP) on the medial aspect of the canine humerus.

Materials and Methods

Anatomic Definitions

Previous humeral IM pin studies describe the medial epicondyle as the nonarticular part of the medial aspect of the humeral condyle.[16, 17] We have identified the medial epicondyle as the palpable and visible prominence on the medial aspect of the humeral condyle. The term medial epicondylar canal describes the bone tunnel in the medial aspect of the humeral condyle through which the pin is

inserted. The medial epicondylar ridge is the outer cortical ridge of bone between the medial epicondyle and the humeral diaphysis proximally (Fig 1).

Identification of Pin Insertion Point

Three-dimensional (3D) reconstructions of previous elbow computed tomography (CT) studies of dogs of a similar size to the Greyhound cohort used in this study were used to help define a repeatable landmark for successful IM pin insertion. Using the fly-by viewing tool (Somaris5 Syngo CT Wizard, Siemens, Berlin, Germany), the 3D image was manipulated by scrolling through slices in the transverse plane until it was possible to obtain a clean line of sight from the caudomedial aspect of the humeral condyle through the medial epicondylar canal and into the medullary canal of the humeral diaphysis. From these studies, it was determined that the IM pin would need to be started at a point caudodistal to the medial epicondyle and close to the axial midline without crossing the articular margin of the medial trochlea ridge (Fig 2).

Subsequent cadaveric dissection of the distomedial aspect of the humeral condyle identified a previously undescribed prominence caudodistal to the medial epicondyle located midway between the medial epicondyle and the caudodistal medial trochlea ridge (Fig 3A). The flexor carpi radialis muscle originates from this prominence. Immediately caudodistal to the prominence is a shallow fossa from which the superficial and deep digital flexor muscles originate. This fossa is consistent with the anatomic location determined on CT and serves as the caudodistal, nonarticular insertion point for distal normograde IM pin placement in this study (Fig 3B).

IM Pin Placement

Ten Greyhound cadavers 2–5 years of age and weighing 28–33 kg were included. The dogs had been previously euthanatized for reasons unrelated to this study and stored at −20°C. At the time of the study, the cadavers were thawed at room temperature and used as entire specimens to mimic the clinical scenario for surgical implant placement. Orthogonal radiographs of left and right humeri were taken to confirm skeletal maturity and the absence of radiographic evidence of disease. The narrowest craniocaudal medullary canal diameter was measured from the lateral radiograph and recorded (Table

1). Based on these measurements, a 3.5 mm trocar tip, nonthreaded IM pin (Steinmann Pin, E&H Stoerk Instrumente GmbH, Emmingen-Litptingen, Germany) was chosen, which was ~35% of the narrowest diaphyseal IM diameter.

Each cadaver was positioned in lateral recumbency with the treated limb down. The elbow was partially flexed at a standing angle and the upper contralateral limb was retracted caudally. A medial approach to the distal humerus was performed on all 20 limbs as previously described.[6, 14] All implant placement was performed by a single ECVS board certified specialist surgeon (MRG). A small incision was made in the deep brachial fascia to facilitate cranioproximal retraction of the flexor carpi radialis tendon and caudodistal retraction of the superficial digital flexor tendon exposing the underlying fossa and Gelpi retractors were used to maintain visualization (Fig 4A). The pin was placed without predrilling and was aimed parallel with the caudal cortex of the medial aspect of the humeral condyle (Fig 4B). The pin was advanced through the medial epicondylar canal and into the medulla of the humeral diaphysis using a battery-powered orthopedic drill (Cordless Driver III, Stryker Instruments™, Kalamazoo, MI). As the pin was driven proximally, some resistance could be felt as the tip of the pin contacted the endosteum of the lateral diaphyseal cortex. The pin was easily driven beyond this point in all specimens and driven until proximal resistance prevented further pin movement. After bilateral pin placement radiographs were obtained to document pin location.

3.5 mm LCP Placement

A 10 hole, 3.5 mm LCP (Veterinary LCP 3.5®, Synthes GmbH, Oberdorf, Switzerland) was selected based on AO guidelines for dogs between 28 and 33 kg.[18] A twist of ~30° was made in the proximal half of the plate before placement to account for the sigmoid shape of the humerus and to ensure the proximal screw holes were positioned over the medial cortex of the humeral diaphysis for locking screw placement. No contouring of the distal part of the plate to the medial epicondylar ridge was performed. The tapered "slipper toe" end of the LCP was tunneled proximally under the brachial neurovascular bundle maintaining contact with the medial aspect of the humeral diaphysis (Fig 5A). The plate was positioned distally so that the cranial edge abutted the caudal surface of the medial epicondyle (Fig 5B).

Screw holes were numbered 1–10 from proximal to distal. Three self-tapping locking screws (Veterinary Locking Screw Stardrive®, Synthes GmbH) were placed proximally (holes 1–3) and distally (holes 8–10). The central 4 holes (holes 4–7) were left empty to simulate an area of distal diaphyseal comminution proximal to the supratrochlear foramen. Screws were placed in the same order in each specimen with the most distal screw (screw 10) placed first and positioned no further distal than the level of the medial epicondyle to avoid penetration of the lateral humeral articular surface (Fig 5B). The most proximal screw (screw 1) was placed next after the plate was aligned on the humeral diaphysis to enable fixed angle bicortical screw purchase for all 3 proximal screws if pin interference was avoided. Subsequent screws were placed in holes 2, 9, 3, and 8.

All screws were placed as locking screws using AO technique.[18] The screws were placed bicortically except where IM pin interference was prohibitive, in which case a monocortical screw was placed. A monocortical screw was used in screw hole 9 in every specimen to avoid penetrating the supratrochlear foramen. After LCP placement, each elbow joint was assessed for crepitus and standard orthogonal views of the humerus were taken to assess implant position.

Dissection and Sectioning of Bone

After completion of the study, all limbs were disarticulated from the cadavers and soft tissues were removed. The articular surface of the humeral condyle and the medial epicondylar ridge were examined for evidence of iatrogenic damage. Each humerus was sectioned in the sagittal midline with a band saw. The extent of cancellous bone proximally and distally and the narrowest IM diameter was measured using digital callipers (Craftright 150 mm Digital Vernier Calipers, Craftright Constructions Pty Ltd, New South Wales, Australia).

Results

The narrowest IM diameter measured radiographically was a mean of 10.2 mm (range 9.1–11.1). The narrowest IM diameter measured anatomically was a mean of 10.0 mm (8.8–10.8; Table 1). Based on

these measurements, the 3.5 mm IM pin used in this study was a mean of 34% (range 32–38) of the radiographic diameter and a mean of 35% (range 32–40) of the anatomic diameter.

The anatomic landmark for pin insertion was consistently identified in each specimen using the technique described. Distal normograde insertion of a 3.5 mm IM pin was possible in all specimens at the described insertion point without causing iatrogenic damage to the medial epicondylar ridge or surrounding articular, soft tissue, or neurovascular structures. Radiographic assessment before plate application showed a similar path for all IM pins, which engaged proximally with the endosteum of the craniolateral cortex of the humerus below the greater tubercule (Fig 6)

Interference with the IM pin when drilling necessitated the use of a locked monocortical screw in 28 of 60 (47%) of the 3 proximal screw holes (Table 1). No pin interference was encountered in any of the distal screw holes. Radiographic assessment showed similar medial plate and screw position in all cases (Fig 7). However, in 1 specimen, the most distal screw was found to have penetrated the articular surface. This was detected by palpable joint crepitus and confirmed after disarticulation of the limb before sectioning.

Sagittal midline sectioning of the bone revealed that cancellous bone extended an average of 16 mm (range 9–23) proximal to the supratrochlear foramen and 66 mm (range 54–76) distal to the greater tubercule proximally (Table 1). The pin path could be traced to the craniolateral cortex of the humerus within the proximal cancellous bone in all specimens.

Discussion

Our study describes a repeatable anatomic landmark for pin insertion and the technique for placement of a distal normograde IM pin in the canine humerus. In addition, we demonstrated that placement of a pin of approximately 35% of the IM diameter using this method could be combined with application of a 3.5 mm LCP with fixed angle, locking screws to the medial aspect of the distal humerus. Iatrogenic damage was limited to 1 case of intra-articular screw placement.

Milgram et al described distal normograde IM pin placement based on the successful exit points of pins from the retrograde component of the study.[17] Their study described medial retraction of the flexor carpi ulnaris, superficial and deep digital flexor tendons before pin placement. Our study found a repeatable method of dissection at a different site located more proximal between flexor carpi radialis and superficial digital flexor tendons to expose a previously undescribed bony prominence and the caudally sloping fossa, which serves as the anatomic landmark for pin insertion. Although not encountered in our study, the authors note from pilot studies that starting the pin proximal to the described position and/or excessive obliquity away from the sagittal midline when driving the pin resulted in penetration of the supratrochlear foramen or medial epicondylar ridge rather than IM passage of the pin.

Two recent humeral distal normograde IM pin studies elected to drive the pins through the proximal humeral cortex in order to evaluate proximity to vital structures.[16, 17] We chose to advance the pins until resistance was felt, mimicking the clinical situation. As a result, the pins were seated more distally, engaging the craniolateral cortex of the proximal humerus. This site was anticipated to include sufficient proximal cancellous bone and sagittal midline sectioning after implant placement confirmed this to be the case.

The pins in our study were left to protrude from the bone distally to facilitate implant removal before sectioning. However, in a clinical situation it is recommended that the pin be driven until proximal resistance countered any further movement, withdrawn distally for 5 mm, then cut and replaced into the bone with a mallet and pin set so as not to impinge on the flexor tendons and to avoid potential ulnar nerve neuropraxia.

Results of plate-rod studies recommend the use of a pin of 30–40% of the IM diameter to increase bending and axial stiffness and reduce plate strain.[10-12] A recent cadaveric study concluded a pin of 36–45% of the IM diameter should be chosen for distal normograde pinning of the humerus in dogs of 25–35 kg.[16] In that study, the IM diameter was measured at the distal 80th percentile of humeral length. In our study, the narrowest medullary canal diameter was determined by visual assessment of

the mediolateral radiographs and subsequently by caliper measurement after sagittal sectioning. As a result of these different methods, relative pin size may be different between studies.

The medial approach to the humerus is recommended for fractures of the distal shaft and supracondylar region.[15] Advantages of this approach are direct access to the middle and distal shaft without overlying musculature and a flat medial surface for plate application.[6] Historically, this approach has been unpopular because of the perception that the lateral aspect of the humerus is the tension band side and technical difficulty with adjacent neurovascular structures.[6] There are currently no definitive biomechanical studies that identify the tension band side of the humerus, but some studies have suggested that distally, the medial aspect is the tension band side making it more appropriate for plate placement.[15]

A 10 hole, 3.5 mm LCP was selected for our study in accordance with AO recommendations for dogs of this size and weight.[18] The plate length was chosen as it adequately bridged a theoretical area of comminution in the distal humeral diaphysis and minimized proximal dissection of the superficial and deep pectoral muscles from their craniomedial attachments. The authors acknowledge that a plate of greater length could have been used to increase plate span length and reduce plate-screw density in accordance with existing recommendations for the use of LCP in comminuted fractures.[19]

In our study, only locking screws were used to model the clinical and mechanical advantages of locking plates as internal fixators.[19, 20] The use of monocortical screws to avoid IM pin interference proximally was observed on 28 of 60 occasions, and 4 of 20 constructs had 3 locked monocortical screws proximally because of pin interference. In a nonlocking plate-rod construct this would create a biomechanical weakness; however, locked screws form a fixed angle, single beam construct that are not as dependent on bone purchase for stability.[21] Therefore, the use of locked monocortical screws has less impact on the stability of a locking plate-rod construct than a traditional nonlocking construct.[12, 19, 22]

The choice to place bicortical screws distally except over the supratrochlear foramen was made in order to engage as much distal cancellous bone as possible. A recent study recommended the use of at

least one distal bicortical screw in supracondylar humeral fractures to avoid monocortical screw pullout from the cancellous bone of the humeral condyle.[8] Interestingly, even with an IM pin that occupied a considerable amount of the medial epicondylar canal, bicortical locking screws were placed every time in holes 8 and 10. This is a significant finding as it was thought before the study that IM pin interference would be a significant issue in the distal fragment. This was not the case for 2 reasons. First, the repeatable insertion point identified in our study ensures passage of the IM pin caudal to the medial epicondyle facilitating plate placement more cranially. Second, the natural caudal slope of the humerus from the medial epicondyle also confers a natural angle to the plate when placed flat on this surface, which directs screws in a caudomedial to craniolateral direction away from the caudally located pin.

Our study was conducted on a Greyhound cadaveric cohort and the anatomic features described may be more difficult to identify in other breeds, especially chondrodystrophic breeds. The central 4 holes of the plate were left empty to simulate an area of distal diaphyseal comminution proximal to the supratrochlear foramen. Our study and all previous studies describing IM pinning of the humerus have used intact cadaveric bone with no fracture gap for repeatability of technique.[16, 17, 23] This repeatability may not translate to the clinical scenario where fracture configuration and ease of reduction and pin insertion varies between cases.

The anatomic landmark and technique described in our study enables repeatable, successful placement of a distal normograde IM pin of approximately 35% of the IM diameter combined with an LCP on the medial aspect of the canine humerus. This technique may be useful for locking plate-rod fixation of distal humeral diaphyseal fractures.

Disclosure

The authors declare no conflicts of interest related to this report.

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Figure 1. Three-dimensional computed tomography reconstruction of a canine elbow. The medial epicondyle (ME) is the palpable and visible prominence on the medial aspect of the humeral condyle. The medial epicondylar canal (ME Canal) describes the bone tunnel in the medial aspect of the humeral condyle through which the pin is inserted. The medial epicondylar Ridge (ME Ridge) is the outer cortical ridge of bone between the medial epicondyle and the humeral diaphysis proximally.
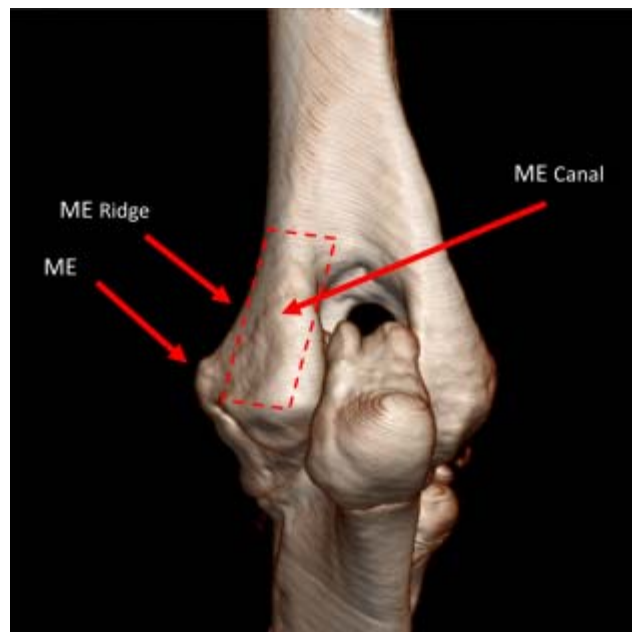
Figure 2. Medial and lateral three-dimensional computed tomography reconstructions of a canine elbow. By manipulating the image and using the fly-by viewing tool, it was possible to obtain a clean line of sight from the caudomedial aspect of the humeral condyle through the medial epicondylar canal and into the medullary canal of the humeral diaphysis. The red dot identifies the anatomic position for distal normograde intramedullary pin placement and P identifies a previously undescribed prominence caudodistal to the medial epicondyle (ME).
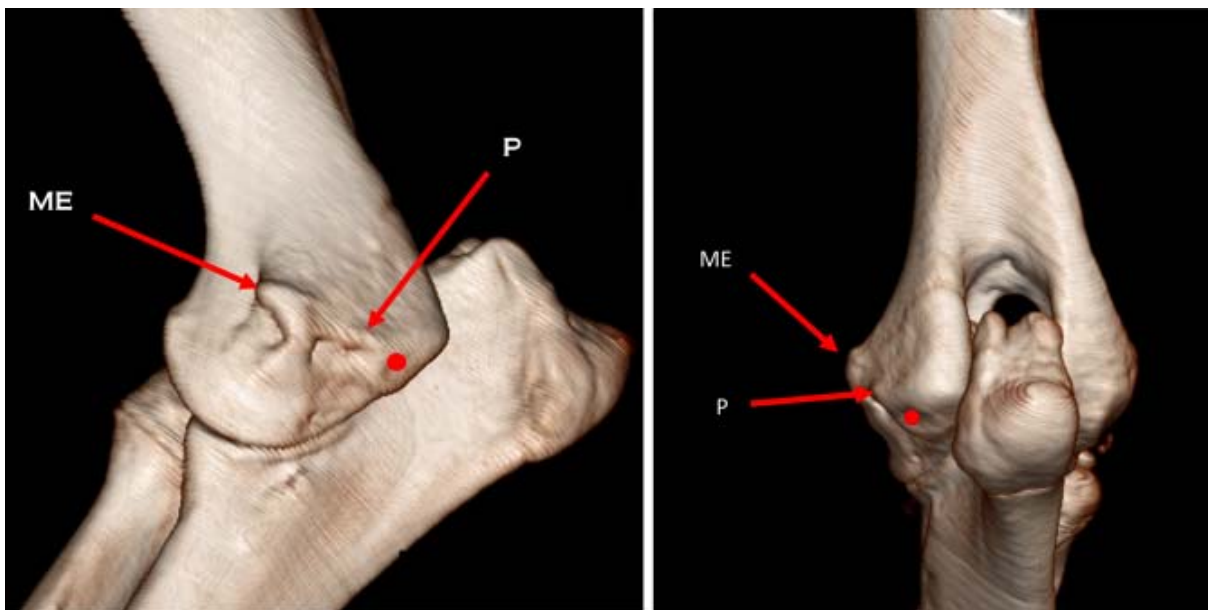
Figure 3. (A) Cadaveric specimen of a canine elbow showing a previously undescribed prominence (P) caudodistal to the medial epicondyle (ME) located midway between the medial epicondyle and the caudodistal medial trochlea ridge. The flexor carpi radialis (FCR) muscle originates from this prominence. (B) Prepared bone specimen showing the shallow fossa (red dot) immediately caudodistal to the prominence (P) from which the superficial (SDF) and deep digital flexor muscles originate. The location of the fossa is consistent with the anatomic location determined on computed tomography and serves as the caudodistal, nonarticular insertion point for distal normograde intramedullary pin placement.
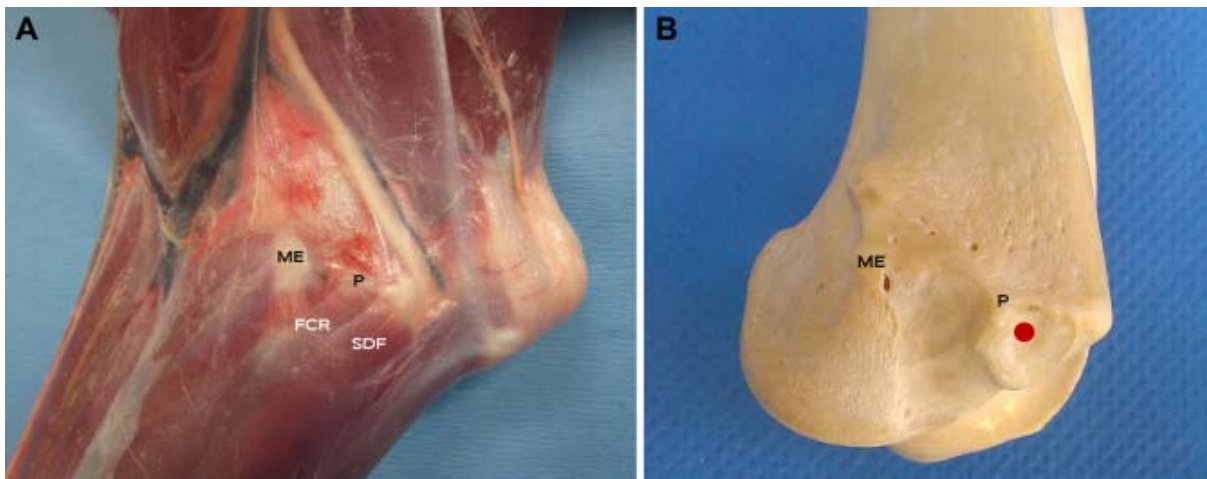
Figure 4. Medial views of canine cadaveric elbow specimen showing (A) the gelpi retractor positioned to maintain cranioproximal retraction of the flexor carpi radialis tendon (FCR) and caudodistal retraction of the superficial digital flexor tendon (SDF) to expose the underlying flexor fossa distal to the previously undescribed prominence (P); and (B) pin placement without predrilling and aiming parallel with the caudal cortex of the medial aspect of the humeral condyle. ME, medial epicondyle of the humerus.
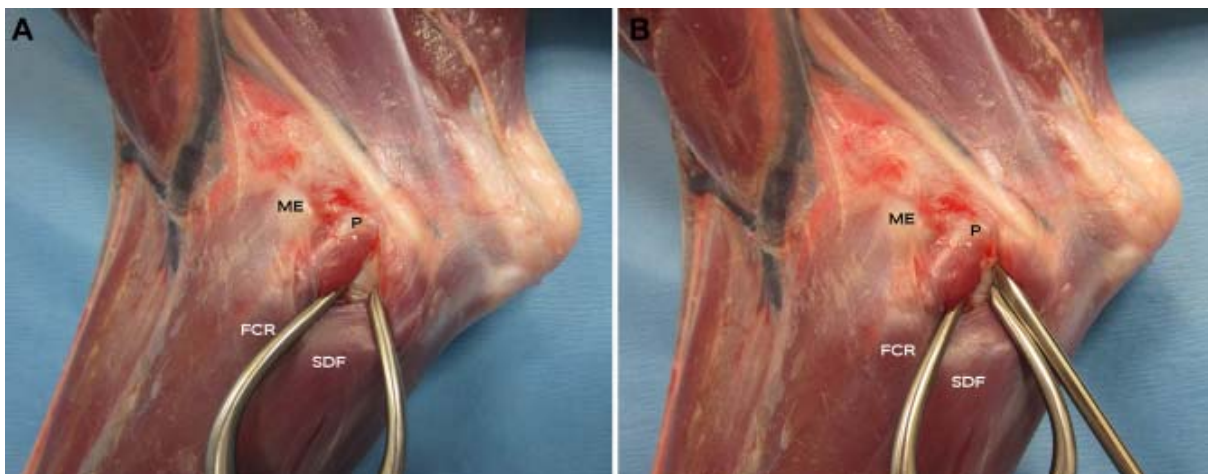
Figure 5. Canine cadaveric specimens. (A) Cranial view showing the tapered "slipper toe" end of the locking compression plate tunneled proximally under the brachial neurovascular bundle maintaining contact with the medial aspect of the humeral diaphysis. The biceps brachii muscle (BB) was retracted medially to facilitate proximal screw placement. (B) Medial view showing positioning of the plate distally so that the cranial edge abutted the caudal surface of the medial epicondyle (ME). The most distal screw (screw 10) was placed first and positioned no further distal than the level of the ME to avoid penetration of the lateral humeral articular surface. FCR, flexor carpi radialis tendon; SDF, superficial digital flexor tendon.
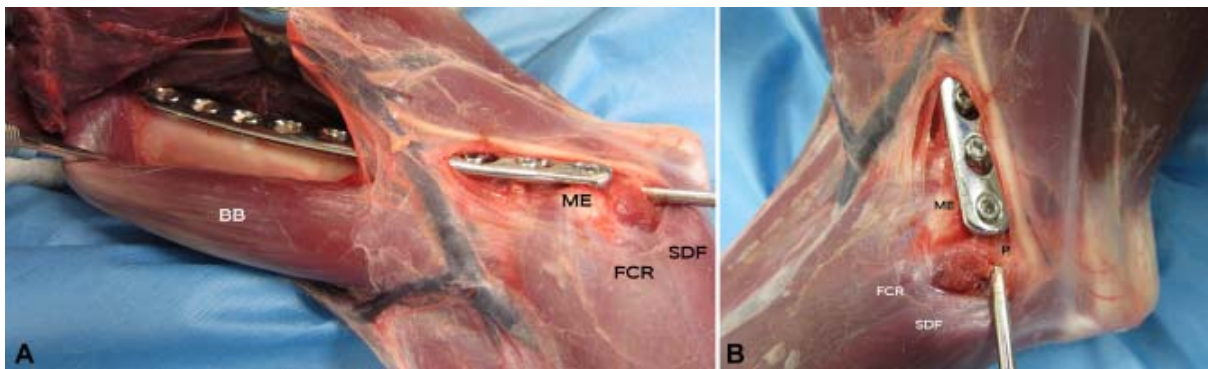
Figure 6. Orthogonal radiographs before plate application showing a similar path for all intramedullary pins, which engaged proximally with the endosteum of the craniolateral cortex of the humerus below the greater tubercule.
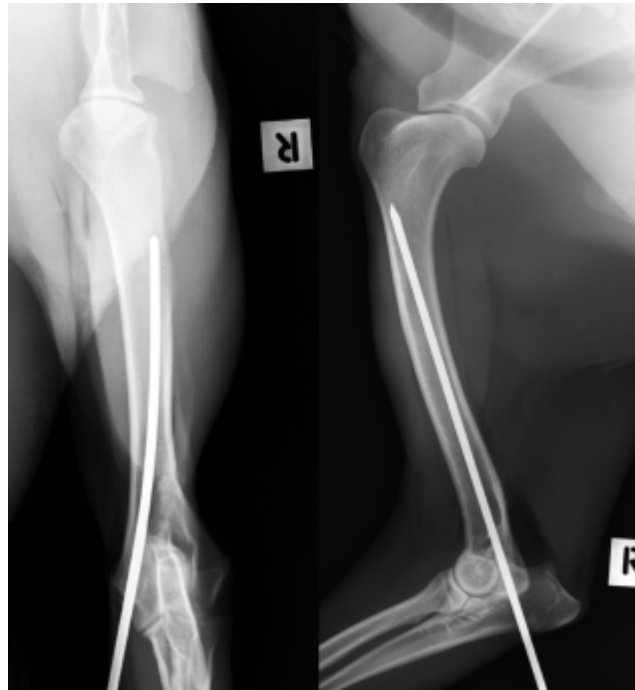
Figure 7. Orthogonal radiographs showing representative medial locking compression plate and pin position achieved in all cadavers.
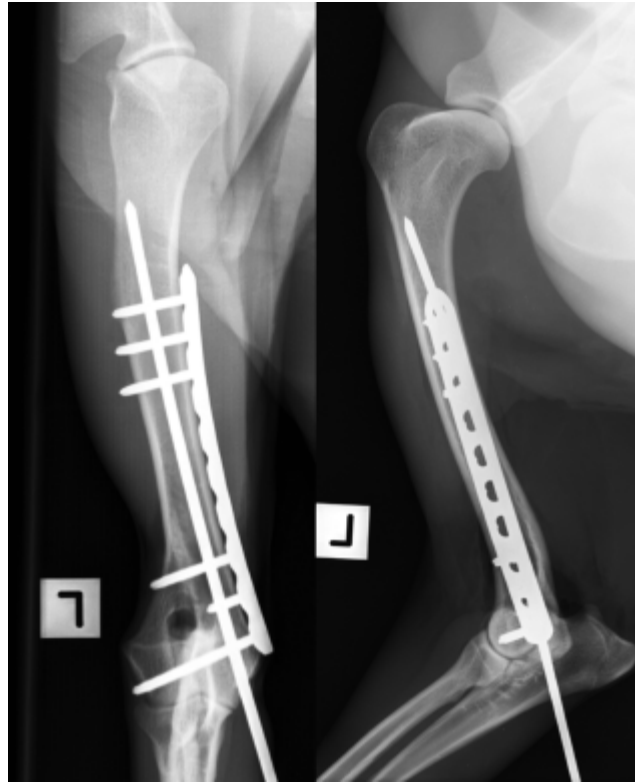
Table 1. Radiographic and cadaveric measurements in 10 canine cadavers after distal normograde

humeral intramudullary (IM) pin and locking compression plate placement

Dog	Weight (kg)	Limb	Number of proximal monocortical screws used	Narrowest radiographic IM diameter (mm)	Radiographic pin/IM diameter (%)	Narrowest cadaveric IM diameter (mm)	Cadaveric pin/IM diameter (%)	Linear extent of cancellous bone (mm)	
								Proximal	Distal
1	31	L	2	9.1	38	9.5	37	65.4	14.2
		R	3	9.5	37	9.8	37	63.7	18.4
2	28	L	1	10.9	32	10.1	35	70.0	20.5
		R	1	10.8	32	10.8	32	70.9	17.6
3	31	L	2	11.1	32	10.6	33	62.5	18.5
		R	0	11.1	32	10.7	33	56.3	22.7
4	26	L	0	10.8	32	10.2	34	72.2	9.2
		R	1	10.8	32	10.6	33	65.8	13.0
5	29	L	0	10.3	34	10.3	34	66.2	12.4
		R	1	10.7	33	10	35	76.2	10.7
6	33	L	2	10.5	33	10.2	34	68.5	15.1
		R	3	10.6	33	9.6	36	75.1	17.7
7	32	L	3	9.3	38	10.4	34	66.4	17.8
		R	1	9.6	36	9.2	38	75.5	13.6
8	28	L	1	9.7	36	8.8	40	62.3	22.1
		R	0	9.2	38	9.5	37	63.5	25.1
9	31	L	2	9.9	35	9.8	36	53.7	11.5
		R	0	9.6	36	9.6	36	56.2	11.3
10	30	L	3	10.6	33	9.9	35	66.7	17.2
		R	2	11.0	32	10.3	34	63.0	18.9
Mean	30		1.4	10.2	34	10.0	35	66.0	16.4