A five-year old springer spaniel that was treated for an intercondylar Y fracture

Humeral condylar fractures and incomplete ossification of the humeral condyle in dogs

ANDY MOORES

HUMERAL condylar fractures are among the most common fractures seen in dogs and account for approximately 20 per cent of the author's canine fracture caseload, although this is a referral population and probably does not represent the true incidence of these injuries. It has long been recognised that spaniels are predisposed to humeral condylar fractures. It is now recognised that many of these dogs have a condition known as incomplete ossification of the humeral condyle (IOHC) that predisposes them to condylar fractures, often occurring during normal activity or associated with only minor trauma. This article discusses the management of humeral condylar fractures and IOHC.

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HUMERAL CONDYLAR FRACTURES

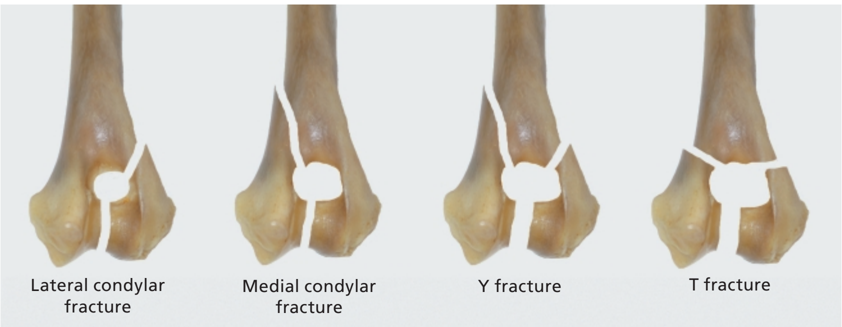
CLASSIFICATION

Humeral condylar fractures can be divided into lateral condylar, medial condylar and intercondylar fractures. Lateral and medial humeral condylar fractures involve only one epicondylar ridge of the condyle. Intercondylar fractures involve both the medial and lateral epicondylar ridges and are commonly described as 'Y' or 'T' fractures depending on the orientation of the fracture lines through the epicondylar ridges. Intercondylar fractures with supracondylar and/or condylar comminution are also occasionally seen.

SIGNALMENT AND PRESENTATION

Humeral condylar fractures may be seen in any breed of dog although spaniels are commonly affected due to their predisposition to IOHC. Lateral condylar fractures are the most common condylar fracture seen. This is thought to be due to two factors. First, the radius articulates with the lateral part of the condyle and therefore the force from sudden impacts is primarily directed laterally. Secondly, the lateral epicondylar ridge is smaller and weaker than its medial counterpart. Lateral condylar fractures are most prevalent in skeletally immature dogs. In one retrospective review, 67 per cent of cases were less than one year of age, the most common age being four months (Denny 1983). Lateral and medial condylar fractures are often associated with a minor fall, although in some dogs with IOHC they can occur during relatively normal activity. Intercondylar fractures are usually, but not exclusively, seen in skeletally mature dogs. They can also be caused by a fall but are generally associated with more severe trauma, such as road traffic accidents (RTAs).

Dogs with a recent humeral condylar fracture present with non-weightbearing thoracic limb lameness. The elbow feels thickened due to the separation of the two parts of the condyle and the associated haematoma and inflammation. Elbow pain and crepitus is evident if elbow manipulation is attempted. The diagnosis is readily made from orthogonal radiographs. It is important



Classification of humeral condylar fractures

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Craniocaudal radiograph of the elbow of a four-month-old puppy. Note the size of the lateral epicondylar ridge in relation to the medial ridge and the articulation between the radial head and the lateral part of the condyle

that two views are taken: the fragments can be superimposed on a mediolateral view giving the appearance of a relatively normal elbow to the inexperienced observer.

MANAGEMENT

If an animal has been involved in a major trauma (eg, an RTA), life-threatening injuries should be evaluated and addressed prior to assessing and treating the fracture. Otherwise, initial treatment should concentrate on the provision of suitable analgesia (generally non-steroidal anti-inflammatory drugs [NSAIDs] in combination with injectable opiates) and confinement of the patient to a kennel or cage. A support dressing is usually not required. Indeed, dressings that only extend a short way proximal to the elbow are counterproductive, serving only to increase the weight hanging from the fracture site. The exception is the spica splint, which may be useful in some situations. This extends around the thorax and incorporates a lateral splint (a malleable bar or strips of fibreglass casting material) that runs from the paw to the dorsal midline and thus provides immobilisation of the upper limb. Humeral condylar fractures are generally closed, but if the fracture is open, wound lavage and intravenous broad spectrum antibiotics are indicated.

Humeral condylar fractures are articular fractures. Therefore, in order to maximise joint function postoperatively the condylar fragments must be accurately reduced and stabilised with rigid internal fixation. This is achieved using a transcondylar lag screw to create compression between the condylar fragments.

A partially threaded 4·0 mm cancellous screw can be used as a transcondylar lag screw. Compression is achieved if the screw's threads interface with the 'far' fragment only (ie, the medial part of the condyle for a lateral condylar fracture). However, the bending strength of a 4·0 mm cancellous screw is only equivalent to a 2·7 mm cortical screw (both screws have the same core diameter) and it is significantly inferior to the bending strength of the larger cortical screws. Thus, in general, an appropriately sized cortical screw is preferred. A cancellous screw may have some advantages in very young dogs with softer epiphyseal and metaphyseal bone, but even in these patients the use of a similarly sized cortical screw is usually successful and preferred due to its greater bending strength.

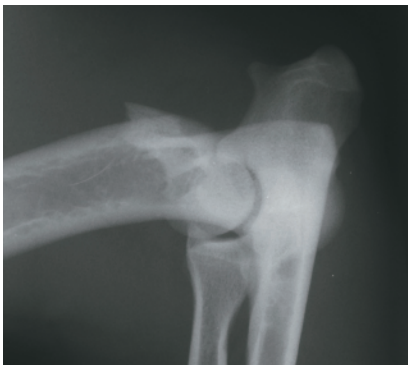
Lateral condylar fractures

Lateral condylar fractures are approached via a slightly curved incision over the distal humerus, passing just cranial to the point of the lateral epicondyle. The underlying subcutaneous fascia is incised in the same line and the deeper brachial fascia is incised along the cranial border of the lateral head of the triceps, allowing caudal retraction of this muscle and exposure of the lateral epicondyle. Care must be taken to avoid the radial nerve deep to the triceps at the proximal extent of the incision.

When a cortical screw is used as a lag screw, compression is achieved by over-drilling the 'near' fragment to create a glide hole. This glide hole can be created either from the 'inside-out' (the author's preferred approach), whereby the hole is started from the fracture surface of the lateral fragment, and exits laterally, or the 'outside-in'. To sufficiently expose the fracture surface, the anconeus muscle is elevated from the caudal aspect of the lateral fragment. Distal-to-proximal elevation of the origin of the extensor carpi radialis muscle will expose the cranial joint capsule, which can then also be incised to free the cranial aspect of the fragment. This allows the cranial articular surface to be inspected and also the accuracy of fracture reduction to be assessed later. Once the soft tissues have been sufficiently released the lateral fragment can be rotated outwards on the lateral collateral ligament and other distal soft tissues.

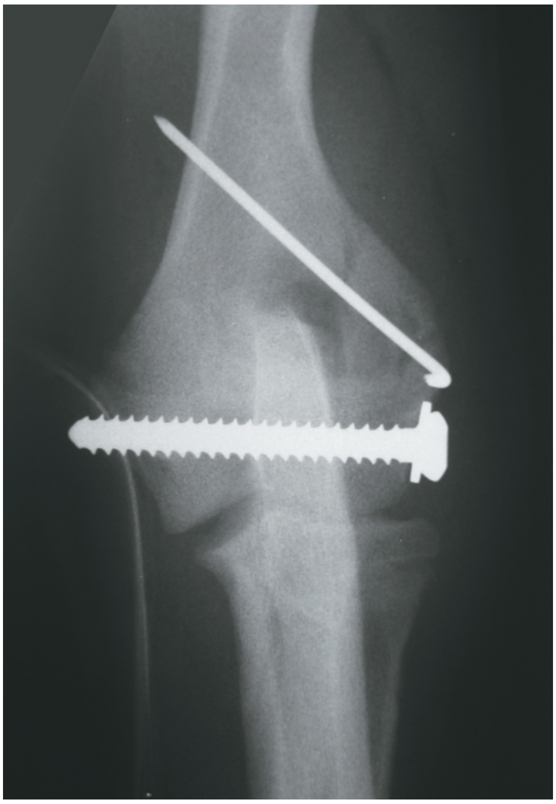
The inside-out approach ensures that the screw passes through the midpoint of the condyle. It also ensures that the glide hole includes all of the lateral fragment and does not encroach on the medial fragment. The alternative, outside-in approach requires reduction of the fracture, followed by drilling of a glide hole from the lateral epicondyle through the lateral part of the condyle to the fracture surface. Care must be taken to ensure that the glide hole only includes the lateral fragment.

It is advisable to use a small drill bit first to check the direction of the drilled hole. The aim is to place the drill hole in the centre of the fractured surface of the condyle and for it to exit the lateral surface slightly cranial and



Mediolateral (above) and craniocaudal (right) radiographs of a lateral condylar fracture in a labrador

Intraoperative view of a lateral condylar fracture in a six-month-old English springer spaniel. The lateral fracture fragment has been rotated outwards prior to drilling the glide hole. Note the sclerotic bone at the fracture surface



Postoperative craniocaudal radiograph of a lateral condylar fracture in a three-month-old spaniel. A 3·5 mm cortical screw and washer have been used to stabilise the condyle, with a K-wire placed through the lateral epicondylar ridge

slightly distal to the most lateral point of the lateral epicondyle. If the direction is satisfactory, larger drill bits can be used to enlarge the glide hole, finishing with a drill bit corresponding to the outside diameter of the screw to be used (ie, a 3·5 mm drill for a 3·5 mm screw). The drill is removed, replaced with a drill bit corresponding to the core diameter of the screw (ie, a 2·5 mm drill for a 3·5 mm screw), and then used to locate the drill hole from the lateral (outer) aspect. The soft tissues are elevated away from the hole so that when a screw is placed it will sit on the bone rather than on the soft tissues in that area. An appropriately sized insert sleeve is guided over the tip of the smaller drill bit and into the glide hole. With the sleeve in place it can be used as a handle to manipulate the lateral fragment. It also serves to prevent the tips of bone-reducing forceps from falling into the glide hole.

The size of the screw chosen will depend on the size of the humeral condyle and the aetiology of the fracture. The outer diameter of the screw is generally 30 to 50 per cent of the diameter of the condyle at the fracture surface. Fractures that are considered to be secondary to IOHC require the largest screw that can be safely accommodated in the condyle. For most springer spaniels this equates to a 4·5 mm cortical screw. A 5·5 mm cortical screw is appropriate for larger dogs. Dogs with fractures that are not thought to be secondary to IOHC can be treated with relatively smaller screws.

Once the fracture surfaces have been cleared of any soft tissues or haematoma that might prevent accurate reduction, the fragments can be reduced. This is achieved by applying distal traction on the limb and at the same time digitally squeezing the medial and lateral fragments together. Fine-tuning of the reduction can be achieved by manipulating the lateral fragment via the insert sleeve. Adequate reduction is achieved if the epicondylar ridge is perfectly aligned and if there is no step evident in the cranial articular surface. Once obtained, the reduction can be maintained with spiked bone reduction forceps placed across the condyle or simply by digital pressure. The core diameter drill bit is then passed through the insert sleeve and a hole is drilled through the medial part of the condyle. The sleeve is removed and the hole is measured and, if non-self-tapping screws are being used, tapped. A screw sufficiently long for its tip to be palpable medially should be chosen. This ensures that the tip can be gripped with pliers and therefore easily removed should the screw break in the future. In young dogs, the addition of a stainless steel washer is advised to prevent the screw head sinking into the soft bone of the epicondyle during tightening.

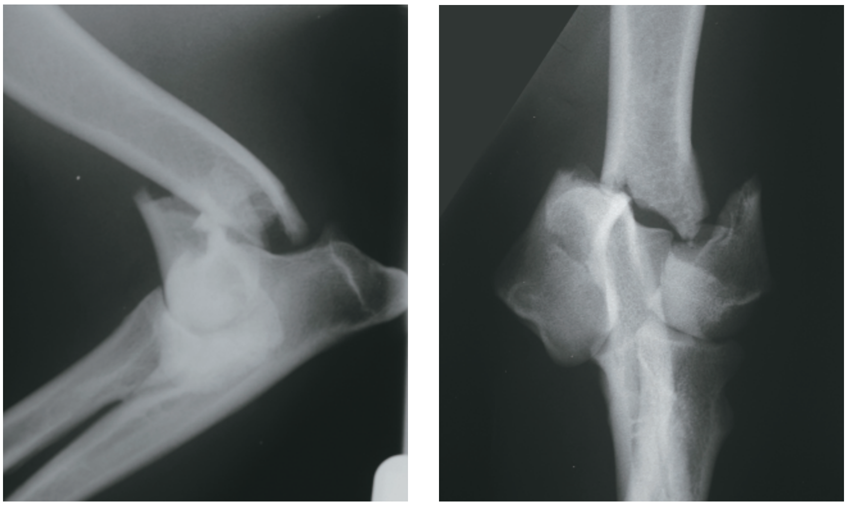
The transcondylar lag screw alone is not sufficient to prevent the lateral fragment from rotating about the axis of the screw. A second point of fixation is required to counter rotational forces. In most cases this is achieved by passing a Kirschner wire (K-wire) from the base of the lateral epicondylar ridge distally, across the fracture of the epicondylar ridge and into the diaphysis proximally. This wire should penetrate the medial cortex of the humeral diaphysis. The wire is cut short, the wound lavaged and the soft tissues closed in a standard manner. Postoperative radiographs are of course essential to assess fracture reduction, implant placement and to allow comparison with follow-up radiographs taken at a later date.

Medial condylar fractures

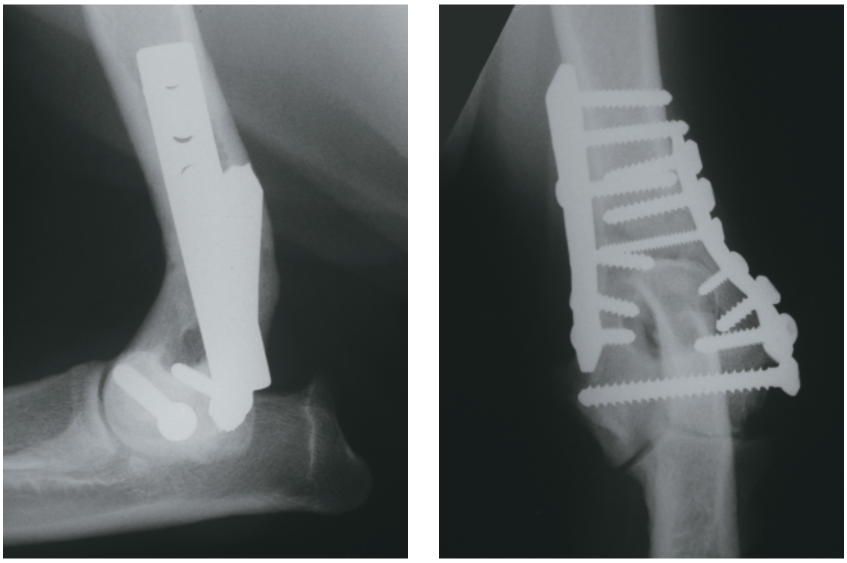
Medial condylar fractures are much less common than lateral condylar fractures, but the principles of treatment are the same. A transcondylar lag screw is placed from the medial aspect and an additional anti-rotational device is required. Medial condylar fractures often have a longer medial epicondylar component that allows a second lag screw, placed proximal to the supratrochlear foramen, to be used as the anti-rotational device.

Intercondylar fractures

Y and T fractures present a challenge and their repair should only be attempted by experienced surgeons. They



Preoperative radiographs of a Y fracture in an English springer spaniel



Postoperative radiographs of the fracture pictured at the top of the page. A bilateral approach has allowed placement of a 3·5 mm lag screw across the condyle, a 2·7 mm dynamic compression plate across the medial epicondylar ridge and a 2·0/2·7 mm Veterinary Cuttable Plate (Synthes) across the lateral epicondylar ridge

can be approached in two ways. Some surgeons favour a caudal approach. This can be performed by tenotomy of the triceps tendon, although this is probably best reserved for very small or very young patients. More often an olecranon osteotomy is performed (see further reading for specific details of this approach). Olecranon osteotomy allows proximal retraction of the triceps muscle and tendon, and exposure of the condylar fragments. The condyle is reconstructed with a transcondylar lag screw and the reconstructed condyle is then attached to the shaft of the humerus. In very small patients, crossed K-wires may be sufficient to achieve this but, in the majority of patients, double plating is the preferred technique. One plate is applied along either the medial or the caudal edge of the medial epicondylar ridge. A second, smaller plate is applied along the caudal edge of the lateral epicondylar ridge. It may also be possible to place a plate along the lateral surface of the lateral epicondylar ridge. Given the curved geometry of the lateral ridge, a reconstruction plate is ideal for this purpose. Care must be taken in placing screws to ensure they do not enter the olecranon fossa and impinge on the anconeal process during elbow extension.

The author's preferred approach for intercondylar fractures is a bilateral approach. This avoids osteotomy of the olecranon and its potential complications but does require that the medial part of the fracture can be accurately reduced. The distal humerus is approached medially first, and the medial condylar fragment is reduced to the humeral shaft and stabilised with a plate. By achieving this the fracture is essentially converted to a lateral condylar fracture. The lateral condylar fragment is subsequently reduced and stabilised with a transcondylar lag screw and a lateral plate via a lateral approach. With the bilateral approach, accurate reduction of the articular surfaces of the condyle from the lateral side can only be achieved if the medial part of the fragment is also perfectly reduced. Thus, intercondylar fractures that appear to have some comminution of the medial epicondylar ridge may be better managed using a caudal approach.

POSTOPERATIVE CARE

In the first 24 to 48 hours postoperatively a light, full limb dressing may be used to limit swelling. Opiate analgesia is provided during this period, but after 24 to 48 hours postoperatively NSAIDs are often sufficient for analgesia and are generally continued for seven to 14 days.

Appropriate exercise restriction during the postoperative period is essential to a good outcome. It is not uncommon for inappropriate exercise during this time to be associated with implant breakage and loss of fracture reduction. The author advises that these patients are either confined to a small room or are cage/kennel rested. They should not be allowed to jump on or off furniture and should be walked out to a garden on a lead several times a day for toilet purposes only. This regimen should continue until fracture union is documented. Strict rest in this fashion maximises the chances of successful fracture healing and does not compromise elbow range of motion. As long as a patient is using the affected limb well postoperatively, specific physiotherapy is generally not required although gentle flexion–extension exercises and hydrotherapy may be useful if restricted mobility is a concern. The most important determinants of good elbow range of motion postoperatively are accurate fracture reduction, careful implant placement and an atraumatic surgical technique, all of which allow near-normal limb use in the postoperative period. If the patient is dramatically lame or non-weightbearing on the limb beyond the first few days postoperatively, fracture instability, displacement of fragments or implants, insufficient analgesia and infection must be ruled out as possible reasons.

Follow-up radiographs are initially obtained four to six weeks postoperatively depending on the age of the patient. Implants are usually not removed unless they are compromising elbow function, have loosened or are associated with postoperative infection.

PROGNOSIS

With early stabilisation, the prognosis for lateral and medial condylar fractures is generally good. The prognosis is more guarded for fractures secondary to IOHC (see later). In a review of 15 humeral condylar fractures followed up for a mean of 43 months, all affected elbows developed post-traumatic osteoarthritis (Gordon and others 2003). This study revealed that the more accurate the reduction, the lower the radiographic osteoarthritis score. These dogs had a reduced range of elbow flexion at follow-up, but elbow extension, which is more important during the gait cycle, was unaffected. Although radiographic evidence of osteoarthritis may develop, in the author's experience this is not associated with a clinical problem in the majority of dogs.

The prognosis for intercondylar fractures is more guarded, with approximately half of dogs having some degree of persistent lameness in one study (Denny 1983). A more recent report of bilateral fixation showed good or excellent short-term limb function in 27 out of 30 fractures (McKee and others 2005).

INCOMPLETE OSSIFICATION OF THE HUMERAL CONDYLE

Although the high incidence of humeral condylar fractures in spaniels had led to a suspicion that there was an inherent weakness or conformational abnormality affecting the humeral condyle of these dogs, the precise nature of this abnormality has only come to light over the past 15 years or so. It is now recognised that some dogs have a sagittal, radiolucent fissure present within the humeral condyle that separates the medial and lateral parts of the condyle and extends from the articular surface to, or towards, the supratrochlear foramen. A fissure is frequently, but not invariably, found bilaterally. Biopsies from fissures have demonstrated fibrous tissue with an increased number of plasma cells and osteoclasts.

All long bones develop from a cartilaginous template known as an anlage. During skeletal development, ossification of the anlage commences at specific locations, or so-called ossification centres. The humeral condyle develops from three such ossification centres: a medial ossification centre, a lateral ossification centre and a smaller ossification centre that forms the medial epicondyle. The larger two ossification centres should fuse at between eight and 12 weeks of age in dogs. The location of the fissure in IOHC corresponds to the location of the cartilaginous plate that separates these two ossification centres prior to their fusion. This has led to the assumption that IOHC is a developmental failure of fusion of these centres – hence the term 'incomplete ossification'. This cartilaginous plate only extends as far proximally as the distal humeral growth plate and yet often the fissures associated with IOHC extend to the supratrochlear foramen proximal to the growth plate. Presumably extension of the fissure into the metaphysis occurs as a result of a stress fracture initiated at the pre-existing weakness.

Radiograph of a distal humerus from the cadaver a seven-week-old labrador. The medial (left) and lateral (right) ossification centres of the humeral condyle are separated by a cartilaginous septum that extends proximally to the distal humeral growth plate

IOHC is most commonly seen in spaniel breeds. In the USA, American cocker spaniels are often affected while, in the UK, English springer spaniels are overrepresented. However, this condition does affect other spaniel breeds and is also seen in a variety of non-spaniel breeds including labradors and rottweilers. In American cocker spaniels, pedigree analysis suggests that the condition may be heritable with a recessive mode of inheritance (Marcellin-Little and others 1994).

Dogs with IOHC may present in one of three ways:
- With lameness;
- With humeral condylar fractures secondary to IOHC;
- Without clinical signs.

DOGS WITH LAMENESS

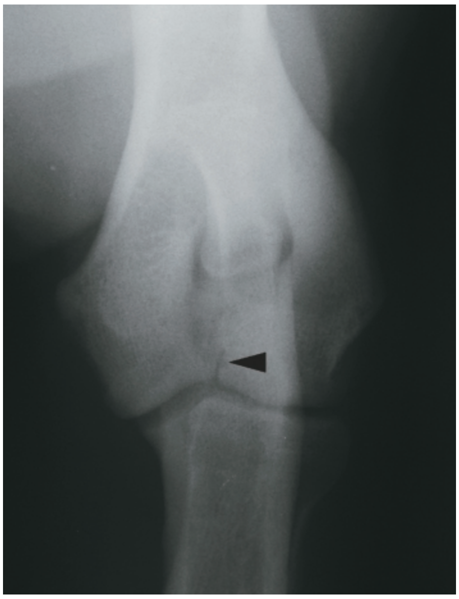
IOHC can cause elbow pain and lameness in its own right. The lameness may be intermittent and mild, or more persistent and severe. It is generally poorly responsive to anti-inflammatory medication. Elbow pain is often most noticeable on extension, but the range of joint motion is not affected and these dogs usually do not have elbow effusions. The exception to this is likely to be dogs with concurrent fragmentation of the coronoid process, which is reportedly common in American cocker spaniels with IOHC, but is a rare finding in the UK in the author's experience.

Diagnosis of IOHC requires demonstration of the condylar fissure. This can usually be achieved with high quality craniocaudal radiographs of the elbow, although often the radiolucent fissure is not evident unless the x-ray beam is directed exactly parallel to the fissure. Several craniocaudal projections may be required, each taken at slightly different angles of rotation. It has been suggested that a 15° craniomedial-caudolateral oblique projection is most likely to demonstrate the fissure.

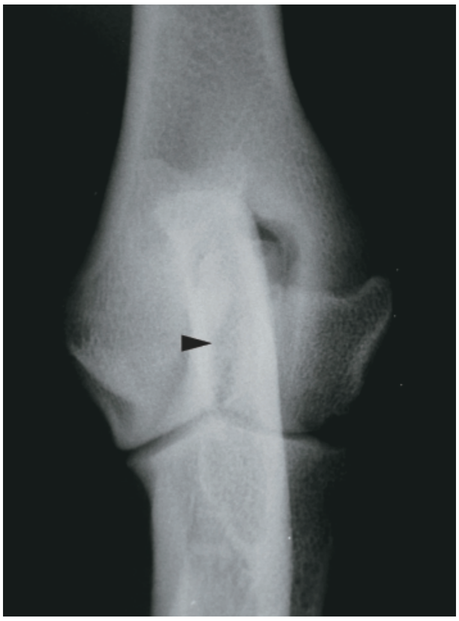
The fissure may be partial, only extending partway to the supratrochlear foramen, or it may be complete, extending all the way. It is important that IOHC is not mistakenly diagnosed on the basis of seeing a mach line – a visual anomaly created by the superimposition of one bone edge on another, which can appear as a radiolucent line through the condyle. New bone, or a periosteal reaction, along the lateral margin of the lateral epicondylar ridge may be seen although, in the author's experience, this is an uncommon radiographic finding.

As it can be difficult to demonstrate a fissure with standard radiography, computed tomography (CT) is the preferred imaging technique. The fissure is readily evident on transverse slices through the condyle. CT additionally reveals areas of increased radiodensity (sclerosis) adjacent to the fissure. Elbow arthroscopy may also be of diagnostic use, revealing a linear fissure in the articular cartilage of the humeral condyle in many affected dogs.

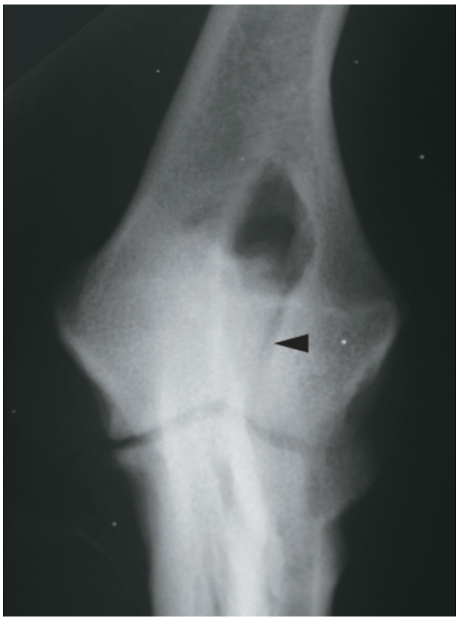
Dogs with IOHC and lameness, without fracture, are treated with a transcondylar screw. A second point of fixation is not required. It is unclear whether this screw should be placed as a positional screw or as a lag screw, although the author has had best results with the latter technique. From a biomechanical perspective the use of



Craniocaudal radiograph of the non-fractured elbow of the same dog as pictured at the bottom of page 392, showing a partial condylar fissure (arrowhead)



Craniocaudal radiograph of an elbow showing a complete condylar fissure (arrowhead)

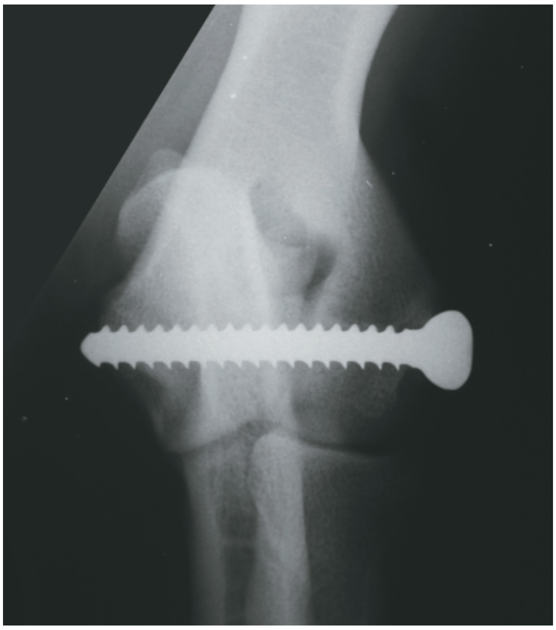


Slightly oblique craniocaudal radiograph of an elbow demonstrating a mach line (arrowhead)

CT images of the elbow of an English springer spaniel demonstrating a humeral condylar fissure (arrowheads). (left) Transverse slice, (middle) two-dimensional (2D) reconstruction in the orthogonal plane, (right) three-dimensional reconstruction. Note the sclerosis of the humeral condyle adjacent to the fissure evident on the two 2D slices

a lag screw would be expected to provide greater resistance against micromovement between the medial and lateral parts of the condyle. An adjustable drill aiming guide is useful to facilitate accurate screw placement in the intact condyle. If placing a lag screw, the depth of the glide hole should be judged from the CT scans or from a craniocaudal radiograph.

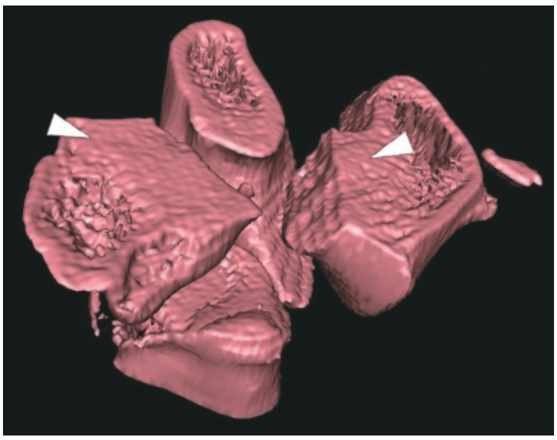
Dogs with IOHC and lameness respond favourably to the placement of a transcondylar screw. Thirteen out of 18 dogs (72 per cent) recovered fully in the combined results from two studies (Butterworth and Innes 2001, Meyer-Lindenberg and others 2002).



Radiograph showing the placement of a 4·5 mm transcondylar lag screw in an English springer spaniel with IOHC

DOGS WITH HUMERAL CONDYLAR FRACTURES SECONDARY TO IOHC

Fractures due to IOHC are most commonly lateral condylar fractures. A history of a humeral condylar fracture occurring during relatively normal activity should arouse suspicions of IOHC, particularly if the dog is a spaniel. Affected cases may also have a history of a prodromal lameness prior to fracture. Identification of a fissure in the contralateral humerus further supports pre-existing IOHC in the fractured humerus. If CT is available to assess these fractures, the intracondylar margins of the fracture will be sclerotic. Sclerosis of the fractured surfaces will also be apparent intraoperatively, and the bone in the centre of the condyle will not be as soft as normal epiphyseal or metaphyseal bone.



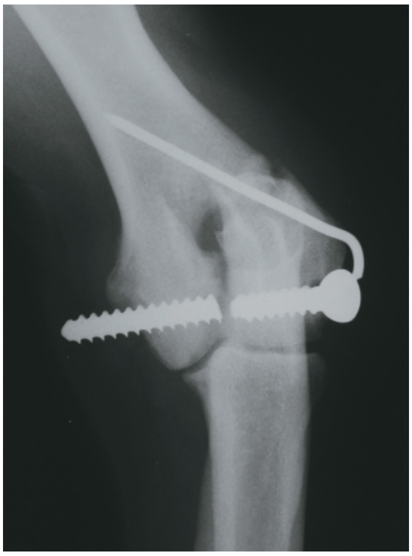
Three-dimensional CT reconstruction of a Y fracture in an English springer spaniel, sectioned through the condylar fragments. Note the sclerosis adjacent to the fracture surface (arrowheads)

The principles of fracture repair are the same as for any humeral condylar fracture, except that there is a greater risk of implant failure due to the reasons highlighted below, and thus the choice of implants may be different to those used to stabilise a standard condylar fracture.

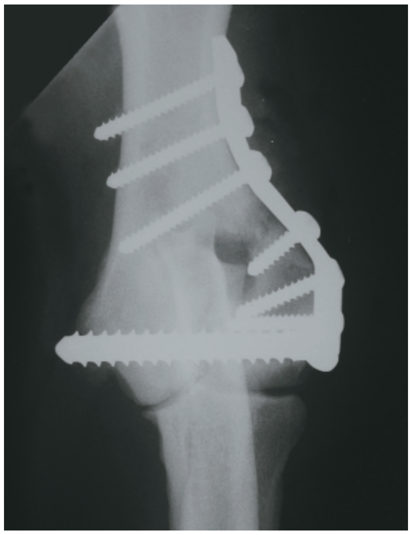
Surgical treatment of condylar fractures secondary to IOHC, and of IOHC in the absence of fracture, should not be relied upon to result in bone union across the fissure. Also, radiographic evidence showing the disappearance of the fissure postoperatively is an unreliable indicator of union. In dogs with apparent disappearance of the fissure on follow-up radiographs, a persistent fissure may be demonstrated on CT examination. Bone union, confirmed with CT, is occasionally seen but is not the norm. More often, follow-up radiographs or CT show a persistent fissure despite transcondylar screw placement. Drilling small bone tunnels across the condyle in an attempt to encourage vascular access to the fissure and thus promote osseous union has been reported with (Butterworth and Innes 2001) and without (Rovesti and others 2002) concurrent placement of a transcondylar screw. Disappearance of the fissure on follow-up radiographs was reported in three out of eight dogs treated with tunnels and a screw. CT examination following treatment with tunnels alone revealed the tunnels and the fissure to be devoid of bone 14 weeks postoperatively. Due to these inconsistent results, the author does not routinely drill tunnels across the condyle.

As the condyle frequently fails to unite following treatment of IOHC or IOHC-associated fractures, there is an increased risk of fatigue failure of the transcondylar screw with subsequent condylar fracture, recurrence of lameness or loss of fracture reduction. For this reason, the largest transcondylar screw that can be safely placed should be used. For most springer spaniels this requires the placement of a 4·5 mm cortical bone screw. Fatigue failure of 3·5 mm cortical screws is not an uncommon finding following the treatment of simple IOHC and the treatment of condylar fractures in springer spaniels. Less commonly, 4·5 mm cortical screws may also break. In this situation, successful revision is often possible with a 5·5 mm cortical screw. Titanium is generally regarded as having better fatigue resistance than stainless steel and thus there may be an advantage in using titanium screws to treat IOHC. Titanium implants should not be used in combination with stainless steel implants.

Reinforcement of the lateral epicondylar ridge may reduce the stress on the transcondylar implant in dogs with lateral condylar fractures secondary to IOHC. With this in mind, it may be appropriate to use a bone plate along the lateral epicondylar ridge, rather than a single K-wire, to counter rotational forces in these cases.



Radiograph showing a broken 4·5 mm screw subsequent to the management of a lateral condylar fracture in an English springer spaniel



Radiograph of the same fracture as pictured on the left following revision surgery. A 5·5 mm cortical screw and 2·7 mm dynamic compression plate have been placed

(left and right) Radiographs showing the management of the fracture pictured at the bottom of page 392 using a 4·5 mm lag screw and 2·7 mm reconstruction plate along the lateral epicondylar ridge

DOGS WITHOUT CLINICAL SIGNS

Occasionally, IOHC will be recognised in an asymptomatic limb, usually following the screening of the 'normal' humerus of a dog with a humeral condylar fracture or a dog with contralateral symptomatic IOHC. The epidemiology of this disease is not currently well understood and it is therefore unclear what the most appropriate course of action is in such situations. The true prevalence of IOHC is unknown in the general canine population, or indeed in spaniel populations, and thus it is impossible to calculate the risk of an affected condyle fracturing for any individual. Placement of a transcondylar screw may reduce the risk of a future condylar fracture in these dogs, but the risks associated with anaesthesia and surgery (eg, seroma, infection) should be weighed against the perceived benefits of screw placement. The relative merits of surgery should be considered in conjunction with the owners on an individual basis for each dog.

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