**AOVET Course – Advanced Techniques in Small Animal Fracture Management**

**Course Notes**

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**1 Introduction to the course**

**Learning objectives**

At the end of this session, participants should be able to:

* Outline a rationale for the course
* Formulate personal aims for the course
* Appreciate the need for lifelong learning

The AOVET competency-based curriculum was developed with the needs of course participants in mind, with the ultimate aim of changing veterinary surgeons’ approach to clinical cases and improving patient outcomes. Although the new courses were designed from scratch using a ‘backwards planning’ model, these new course represent an evolution of the traditional courses which have been so well received in the past, rather than a complete change in approach.

Several courses have been developed, including Principles of Small Animal Fracture Management, Advanced Techniques in Small Animal Fracture Management, and a selection of highly specialized Master courses covering topics such as corrective osteotomies, feline orthopaedics, distal limb surgery, and spinal orthoaedics. The intention is that participants will take the Principles followed by the Advanced course, and will then have access to a menu of Master courses. In conjunction with other AOVET offerings such as webinars this allows participants to engage in a program of lifelong learning.

The new Advanced course consists of a balance of lectures, plenary (whole group) case discussions, small group case discussions, and practical exercises using dry bones. This balance of educational techniques allows essential concepts to be understood and subsequently applied to clinical cases.

**2 Biological and mechanical considerations for long bone fractures**

**Learning objectives**

At the end of this session, participants should be able to:

* Explain the relevance of biological and mechanical considerations when formulating a plan for management of complex fractures
* Recognise how decisions regarding biological and mechanical considerations can positively and negatively affect outcomes

The main objective of the treatment of any fracture is the early return of the patient to full function. The key to achieving this goal is the detailed planning of the entire surgical procedure and postoperative care. Failure to plan and anticipate problems associated with fracture repair consistently results in prolonged operating time, excessive soft-tissue trauma, and technical errors. An ill-prepared surgeon will invariably experience a higher complication rate due to infection, implant failure, delayed healing, and non-union.

Patient considerations, such as age, weight, the presence of concurrent injuries and its overall general health, the expected activity level and intended use of the animal, and the ability of the owner to perform postoperative care should all be carefully considered when choosing the method of fracture repair. In addition, the fracture must be evaluated to determine the mechanical forces acting on the bone as well as the biological effects of the fixation in light of the trauma.

In considering the fracture, the surgeon must ascertain whether full reconstruction of the bone column is possible. Restoration of the bone permits sharing of the weight-bearing load with the implant and will protect the implant from fatigue and early failure. Typically, reconstruction and compression of fragments results in ‘absolute stability’ and primary bone healing can be seen. An unreconstructed fracture relies solely on the implant to sustain axial loading. This may be preferred for comminuted fractures, but implants bearing the majority of the load in an unfavourable mechanical environment must be larger, stronger, and more stable for extended periods of time. In this situation ‘relative stability’ is achieved, and healing is typically by callus formation (secondary bone healing). Animals with polytrauma or multiple orthopaedic injuries will place greater demands on implants as they may be forced, prematurely, to take weight on an injured limb.

The biological environment of the fracture must also be taken into consideration. Young animals with an active periosteum, and metaphyseal fractures with an abundance of cancellous bone, are quick to heal in most situations. Conversely, comminuted high-energy fractures may have impaired vascularity and thus longer healing times can be anticipated. Geriatric or debilitated animals, or animals that have sustained substantial soft-tissue injury, will experience prolonged healing times which necessitate the need for stable implants for more extended periods of time. Once information regarding the patient has been obtained and the mechanical and biological environment of the fracture is known, a decision regarding the appropriate type of fixation may be made. The surgeon must decide whether open or closed reduction is preferred based upon fracture location and complexity, and the type of fixation selected. Open reduction allows for bone grafting and anatomical reconstruction of articular and comminuted fractures, but it has the disadvantage of prolonging surgery time and impairing blood supply. Closed reduction of fractures preserves the blood supply and biology of the fracture but potentially at the cost of fracture fragment alignment.

In order to help processing these thoughts, the data obtained can be summarised as a fracture-assessment score that reflects the mechanical, biological and clinical environment in which the implants must function and guides the type of implant chosen.

In summary there are three factors that should always be considered when planning a fracture repair:

* Mechanical: How stable the fracture would be after reduction; which forces are acting on the fracture site; bodyweight, other injuries, level of activity; is the fracture reconstructable, and importantly does the mechanical advantage of reconstruction outweigh the biological disadvantage of fragment manipulation.
* Biological: this considers the health and healing potential of the fracture, and the overall patient health. A comminuted fracture is worse than a simple fracture. The healing potential of a puppy is greater than the healing potential of an old dog with concurrent diseases such as an endocrinopathy.
* Clinical: Anticipated compliance from owner; dog’s nature (active vs couch potato), environment (living in a bungalow or in a flat without lift)

All these factors are considered; a detailed plan for fracture treatment can then be developed, along with back up plan B and plan C.

**References**

Abercromby R. Preoperative assessment of the fracture patient. In: BSAVA Manual of Small Animal Fracture Repair and Management, 2nd edition. Edited by Gemmill TJ and Clements DN. BSAVA, Cheltenham, UK. 2016

**3 Locking plate systems**

**Learning objectives**

At the end of this session the participant should be able to:

* Explain how locking plates function
* Discuss advantages and disadvantages
* Identify indications and contraindications
* Critically evaluate different types of locking plate

Locking plate systems were developed in the 1990s aiming to reduce bone resorption under conventional plates resulting from damage to the periosteal blood supply. The locking mechanism between screw and plate-hole provides angular stability increasing the construct strength, and reducing implant to bone contact. Stability does not depend on compression of the plate onto the bone as with conventional plates, and therefore periosteal blood supply is preserved. These factors can contribute to decreased healing time and risk of infection.

Locking plate systems, also known as internal fixators, do not need to be contoured exactly to fit the bone, thus in some cases making handling simpler, surgical time shorter, and reducing the possibility of primary loss of reduction as implants are applied. Conversely, unlike conventional plate systems, pre-contoured locking implants cannot be used to assist reduction of the fracture.

Several different locking plate systems are available, using different mechanisms of securing the screws to the plate; fixed and variable angle systems are available. The locking compression plate (LCP) is slightly different. This implant has a combi-hole which allows placement of either a conventional cortical bone screw in a traditional fashion, or placement of a locking screw. This makes the LCP a very versatile implant.

**References**

Perren SM: Evolution and rationale of locked internal fixator technology. Introductory remarks. Injury 2001;32(Suppl2):B3– B9

Perren SM: Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J Bone Joint Surg Br 2002;84:1093–1110

Schwandt CS, Montavon PM: Locking compression plate fixation of radial and tibial fractures in a young dog. Vet Comp Orthop Traumatol 2005;18:194–198

**4 Interlocking nails**

**Learning objectives**

At the end of this session, participants should be able to:

* Describe and explain how interlocking nails function
* Recognise advantages and disadvantages
* Identify indications and contra-indications
* Critically evaluate different types of interlocking nails including angle-stable systems
* Describe how to apply an interlocking nail

Interlocking nails consist of a nail placed in the medullary canal of the bone, and screws or bolts that are placed transversely through the bone and through holes in the nail. Mechanically, the nail is strong as it has a large area moment of inertia and is placed in the neutral axis of the bone, hence bending forces are very well resisted. The placement of the interlocking screws or bolts allow resistance to other forces such as axial collapse and torsion.

Early versions of interlocking nails had reasonable success but complication were not uncommon, including screw and nail breakage. Whilst these complications were reduced by re-engineering of the nail and use of locking bolts rather than screws, some concerns remained as the relatively poor fit between the bolt and nail allowed some movement, and hence interfragmentary strain at the fracture site was less well controlled. In addition, this movement at the fracture site could result in morbidity and poor limb function in the early postoperative period.

More recently, an angle stable nail has been produced, where the bolts lock securely into the nail. This angle stable nail (ILOC, BioMedtrix) allows better control of interfragmentary strain and lower morbidity.

Interlocking nails are commonly used for diaphyseal fractures of the femur, tibia and humerus; use in the proximal ulna has also been described. Implants are placed in a normograde fashion with the bolts placed using a jig; intra-operative fluoroscopy can also be helpful, but is not essential. ILNs can be placed in a minimally invasive fashion.

**References**

Déjardin LM, Guiot LP, von Pfeil DJ. [Interlocking nails and minimally invasive osteosynthesis.](https://www.ncbi.nlm.nih.gov/pubmed/23040301) Vet Clin North Am Small Anim Pract. 2012 Sep;42(5):935-62

**5 Combining implant systems – plate-rod and double plating**

**Learning objectives**

At the end of this session, participants should be able to:

* Identify indications for plate-rod and double plating techniques
* Explain the advantages and disadvantages of plate-rod and double plating techniques
* Describe how plate-rod and double plating techniques are performed

Plate-rod refers to the combination of an intramedullary (IM) pin with a bone plate and screws. This technique is particularly useful in comminuted shaft fractures where the implants will bear all of the load during the initial healing period. The bone plate resists axial collapse and rotation, while the IM pin acts to resist bending in all directions.

Combining an IM pin with a bridging plate reduces plate strain and increases construct stiffness. This increases the fatigue life of the construct whilst decreasing the risk of plastic deformation. Choosing the correct pin size is essential for optimal biomechanics. Hulse et al (2000) compared the reduction of strain in a 3.5 mm dynamic compression plate at the level of the screw hole with IM pins of 30, 40 or 50% medullary diameter in a 20 mm fracture gap (2 empty screw holes). To summarise, for each 10% increase in canal filling, plate strain was reduced by 20%. Construct stiffness increased by 6%, 40% and 78% with IM pins of 30, 40 and 50% medullary canal diameter respectively. Undersizing the pin can have significant consequences for construct strength; using an IM pin that occupies only 25% of the medullary canal reduces strain on the bone plate by only 10%. In clinical scenarios, IM pins that occupy 50% of the medullary canal may be too rigid to permit micromotion to stimulate fracture healing and may impede bicortical screw placement.

For the above reasons it is recommended that, when used in combination with a bone plate, the IM pin should occupy 35-40% of the medullary canal; this reduces strain on the plate by 50% and extends the fatigue life of the implant 10-fold whilst still allowing room to place bicortical bone screws. Alternatively, a larger IM implant can be applied as the primary implant, with a smaller plate used to resist rotational forces. In this instance, monocortical screws can be used, however, in a locking construct at least one monocortical and one bicortical screw should be placed per segment.

Plate-rod constructs can be applied using biological osteosynthesis; ‘open but do not touch’ or minimally-invasive plate osteosynthesis (MIPO). Indirect fracture reduction maximally preserves the biology of the fracture area. The IM pin is placed first and acts to restore spatial alignment (rotation, varus-valgus, length). The IM pin may be introduced normograde or retrograde, depending on the bone and surgeon preference, although retrograde will disrupt the fracture haematoma. The bone plate is applied to the major fracture fragments proximal and distal, bridging the fracture gap. Pre-contouring the plate from a radiograph of the contralateral limb can more easily restore alignment and reduce surgical time. If locking plate systems are utilized, monocortical screws can be used in areas where the screw may impinge on the IM pin. A longer bone plate than normal is often used to permit bicortical screw placement in the larger flared metaphyseal regions of the bone.

Double plating acts to increase the stiffness of a repair, and is useful in areas where an IM pin may not be appropriate. The most common indications for double plating are in areas of poor bone stock or quality, such as peri-articular fractures, as reinforcement where there are concerns regarding mechanical stability (for example, comminuted fractures in large-giant breed dogs, where the primary bone plate is not applied to the tension surface of the bone or has a low area moment of inertia in a specific plane (Morris et al, 2016)), or if suboptimal patient and/or owner compliance is anticipated. Double plating increases construct stiffness and fatigue life, however, can result in significant soft tissue disruption, particularly when bilateral approaches are necessary.

Double plating may be performed in several ways;

1. Bone plates can be applied on either side of the bone (bilateral or parallel plating), such as for Y-fractures of the distal humerus. The use of monocortical screws in locking plates can mitigate screw impingement when applying plates bilaterally.
2. Dual orthogonal plating (perpendicular plating) can be performed, for example plating both medial and cranial aspects of the tibia.
3. Bone plates can be applied to paired bones, for example to both the distal radius and ulna.
4. Two plates may be applied to the same bone surface, for example in stabilisation of tibial plateau leveling osteotomy in giant breed dogs.

**References**

Hulse D, Ferry K, Fawcett A, et al: Effect of intramedullary pin size on reducing bone plate strain Vet Comp Orthop Traumatol 2000;13:185-190, 2000

Morris AP, Anderson AA, Barnes DM, et al: Plate failure by bending following tibial fracture stabilisation in 10 cats. J Sm Anim Pract 2016; 57(9):472–478

**6 Minimally invasive osteosynthesis**

**Learning objectives**

At the end of this session, participants should be able to:

* Assess and define fractures that will benefit from a MIO approach
* Relate biological and mechanical concepts to the application of MIO
* Describe how to apply implants in a minimally invasive fashion
* Anticipate challenges and complications

MIO involves indirect, closed reduction of a fracture followed by application of implants through small incisions away from the fracture site. MIO represents an evolution of biological osteosynthesis, allowing for fracture reduction and provision of stability whilst preserving fracture site biology, however all the basic AO principles of fracture management still apply. Initially, ESF was used however this is associated with a relatively high postoperative complication rate. More recently internal fixation has been used, either interlocking nails or more commonly plates and bone screws.

Long plates are used which span the full length of the bone. This strategy maximises the mechanical integrity of the implants and decreases forces on the screw / bone interfaces. Conventional non-locking plates or locking implants can be used. There is no clear advantage to either locking or non-locking implants, and hence implants should be selected on a case-by-case basis.

Screws are generally placed away from the fracture site at the end of the bone. Stress on the plate is therefore dissipated over a long length of the implant and stress concentration is reduced; the ‘working length’ of the plate is increased. In most cases 3 screws (6 cortices) per principle fragment is appropriate; this usually equates to a screw density (number of screws per number of plate holes) of around 0.5.

Challenges associated with MIO include:

* Difficult to achieve reduction and alignment of principle fragments
* High stress on implants placed in bridging fashion
* Can be technically challenging and time consuming

Solutions to these challenges include:

* Case selection – MIO is most suitable for comminuted mid diaphyseal long bone fractures in medium or large breed patients. Reduction and compression of simple fractures to achieve absolute stability is more challenging, hence simple fractures are usually best treated by open reduction.
* Reduction of the fracture – this can be facilitated by placement of an i/m pin prior to plate application, use of a reduction table, of use of temporary intraoperative ESF. Intra-operative radiography or fluoroscopy can be useful to assess reduction in theatre
* Mechanically robust bridging fixation should be used. Plate-rod or orthogonal plate techniques can be especially useful

Favourable clinical reports have been published regarding MIO techniques in small animals, especially for comminuted long bone fractures. However for many fractures it has not been possible to demonstrate a clear advantage over ‘open but do not touch’ techniques where an approach is made to the fracture site but soft tissue dissection close to the bone is minimized.

**References**

Hudson CC, Pozzi A, Lewis DD (2009). Minimally invasive plate osteosynthesis: applications and techniques in dogs and cats. Vet Comp Orthop Traumatol. 22, 175-82

Guiot LP, Déjardin LM (2011). Prospective evaluation of minimally invasive plate osteosynthesis in 36 non-articular tibial fractures in dogs and cats. Vet Surg. 40, 17

Boero Baroncelli A, Peirone B, Winter MD, Reese DJ, Pozzi A (2012). Retrospective comparison between minimally invasive plate osteosynthesis and open plating for tibial fractures in dogs. Vet Comp Orthop Traumatol. 25, 410-7

**7 Bone grafts and bone graft substitutes**

**Learning objectives**

At the end of this session, participants should be able to:

* Recall the rationale for the use of bone grafts
* Compare and contrast bone grafts and alternatives
* List indications for bone grafts and alternatives

Autogenous cancellous bone grafting can contribute to formation of new bone and healing of fractures and osteotomies vai several mechanisms.

* **Osteogenesis**: The cellular elements within a donor graft, which survive transplantation and synthesize new bone at the recipient site.
* **Osteoinduction**: New bone produced through the active recruitment of host mesenchymal stem cells from the surrounding tissue, which differentiate into bone-forming osteoblasts. This process is facilitated by the presence of growth factors within the graft including bone morphogenetic proteins (BMPs).
* **Osteoconduction**: The facilitation of a bone healing process into a defined passive trellis structure.
* **Osteointegration**: The ability to bond to a bone surface without intervening fibrous tissue

ACBG is the only graft material that has all four of the above properties. Unfortunately, ACBG also has several drawbacks, including additional anaesthetic time needed for graft harvesting, the potential for an insufficient quantity of graft, limited access to donor sites, loss of osteogenic cells, donor site pain or hemorrhage, and fracture of the donor bone.

**Alternatives to Bone Graft**

Several alternatives to bone grafts have been studied and used clinically.

* Bone Marrow Aspirate
* Platelet rich plasma
* Demineralised bone matrix (DBM)
* Canine and feline osteoallograft
* Bone morphogenic protein

Of these products, DBM is readily available and has been shown to be effective for use for fractures, osteotomies and arthrodeses. Allogenic chips can be useful as a void filler but have limited other benefits. BMPs can be extremely useful however their use is limited by availability and costs.

**References**

Gemmill TJ and Clements DN. BSAVA Manual of Canine and Feline Fracture Repair and Management, 2nd Edition, 2016

**8 Mini implants**

**Learning objectives**

At the end of this session, participants should be able to:

* Explain the relevance of mini-implants and their importance in small dogs and cats
* Discuss advantages and disadvantages
* Identify indications and contra-indications
* Recognize and critically evaluate different types of mini-implants including locking and non locking implants

Fixation of small bones and fragments can be challenging and an inventory of different implants is needed to cover different fracture situations. Screw size should ideally not exceed 25% of bone diametre to avoid iatrogenic fracture.

**Veterinary cuttable plate**

The Synthes VCP comes in two sizes (1.5/2.0mm and 2.0/2.7mm). 2.4mm screws can be used with either plate. The plates as sold are 300mm or 50 holes long and can be cut to length using pin cutters. The hole-hole distance is 6mm. The plates can be stacked to increase their strength. Different profile plates are available from other companies; in practice a selection of implants from different companies is desirable to cover different situations.

**Mini plates and screws**

Whilst inherently weaker than larger implants, the 1.5 and 2.0mm plates and screws have the obvious advantage that they are small and hence appropriate for stabilisation of small fragments in smaller patients. DCPs or LCPs are commonly used. The development of different shaped plates such as T-plates and L-plates has made the systems more versatile. Recently cuttable notched head locking T-plates have also been introduced (the ‘Mickey mouse’ plate).

1.5mm and 2.0mm cortex or locking screws are available; 1.1mm and 1.5mm drills are used, respectively. Screw heads can have cross head, star drive or mini hex designs.

Clinical indications include stabilisation of juxta-articular fractures with limited bone stock (especially distal radial and caudal ilial fractures); T-plates are especially useful in this situation. DCPs can be useful for some diaphyseal fractures in small patients, although often the plates are too small and hence VCPs are used more commonly.

The 2.4mm system includes a full range of DCPs and LCPs from 4 to 18 holes and screws from 6mm to 40mm. 2.4mm cortex screws can also be used with 1.5/2.0mm and 2.0/2.7mm VCPs. For LCP, 2.4mm and 2.7mm locking screws are interchangeable.

The pilot drill hole is 1.8mm, the glide hole for lag screws is 2.4mm. Self-tapping and non-self-tapping cortex screws are available; locking screws are self-tapping. The clinical indications are similar to other mini-systems or VCPs.

**Super mini implants**

A number of companies now manufacture very small plate and screw systems, typically using 1.0mm or 1.2mm screws. Cortical and locking systems are availabe. These systems are very useful for tiny patients with juxta-articular fractures. Inevitably, the implants are relatively weak and precautions must be taken to avoid implant failure.

# References

Fruchter AM Holmberg DL (1991). Mechanical analysis of the veterinary cuttable plate. VCOT 4, 116-9

Nelson TA, Strom A. [Outcome of Repair of Distal Radial and Ulnar Fractures in Dogs Weighing 4 kg or Less Using a 1.5-mm Locking Adaption Plate or 2.0-mm Limited Contact Dynamic Compression Plate.](https://www.ncbi.nlm.nih.gov/pubmed/29202508) Vet Comp Orthop Traumatol. 2017 Nov;30(6):444-452

**9 Fractures of the distal radius and ulna in toy breeds**

**Learning objectives**

At the end of this session, participants should be able to:

* Describe the surgical approach to the distal radius in toy breeds
* Recognise the mechanical and biological challenges presented by distal radial fractures
* Critically analyse and compare different fixation strategies
* Explain in detail how to apply a dorsal plate and screws
* Anticipate complications

Fractures of the distal radius and ulna in toy breed are challenging to treat. Bone fragments are small, and bone stock very limited, blood supply is reduced compared the same area of large breeds of dogs, and risk of complications/non-union is high.

External coaptation leads to about 83% failure rate, making this a non-acceptable option to treat these fractures. Atrophic non-union is commonly seen associated with these fractures

Keys to obtain successful outcomes are:

* Anatomical reduction and interferometer compression.
* Rigid stabilization
* Protection of blood supply

Fracture stabilisation can be achieved with the use of mini external fixators as the FESSA or circular systems, or with the use of mini plates. T plates allow positioning of sufficient screws in the distal fragment.

External fixators may protect better the cortical vascularity, but make anatomical reduction/compression more difficult. Although successful use of ESF has been described, in most cases internal fixation using locking or non locking plate systems is preferred. Given the inherent weakness of mini implant, there is a significant advantage to compression of simple fractures. This creates absolute stability and load sharing between the implant and bone, which protects the plate against failure.

Once the fracture is healed, staged external fixator/plate removal may be needed to prevent re-fracture.

**References**

JA Welch, RJ Boudrieau, LM DeJardin, et al.: The intraosseous blood supply of the canine radius: Implications for healing of distal fractures in small dogs. Vet Surg. 26:571997 9123814

MH Hamilton, SJ Langley-Hobbs: Use of the AO veterinary mini “T” T -plate for stabilization of distal radius and ulna fractures in toy breed dogs. Vet Comp Orthop Traumatol. 18:18 2005 16594212

LJ Larsen, JK Roush, RM McLaughlin: Bone plate fixation of distal radius and ulna fractures in small and miniature breed dogs. J Am Anim Hosp Assoc. 35:243 1999 10333265

Hass B et al. Use of the tubular external fixator in the treatment of distal radial and ulnar fractures in small dogs and cats. VCOT(2003) 16, 132-137

**10 Humeral condylar fissures**

**Learning objectives**

At the end of this session, participants should be able to:

* Distinguish the aetiology of acquired humeral condylar fissures from developmental IOHC
* Recognise challenges in management
* Describe the advantages and disadvantages of different diagnostic tests
* Formulate management plans
* Anticipate and manage challenges and complications

Humeral condylar fissure (HCF) refers to the development of a sagittal fissure across the centre of the humeral condyle. The term *incomplete ossification of the humeral condyle*, or IOHC, implies a congenital or developmental bone defect, but it has been suggested the condition may be acquired later in life in some patients and hence may be better termed a ‘humeral condylar fissure’ rather than IOHC.

The aetiopathogenesis of the condition is unclear, but two theories have been proposed.

1. The HCF corresponds to the location of the cartilaginous plate that separates the medial and lateral centres of ossification of the humeral condyle in young dogs. Failure of fusion of these ossification centres could allow the development of a fissure. This mechanism may be more likely in younger patients.
2. In some cases the HCF appears to develop in adult dogs. It has been proposed that the fissure could be a form of a stress or fatigue fracture, or could develop secondary to an inherent weakness in an apparent normally ossified condyle (an insufficiency fracture).

Identification of HCF can be challenging, especially for partial fissures. Craniocaudal radiographs can be helpful, especially if oblique projections are also obtained, although radiographs are somewhat insensitive. CT is the gold standard; use of MRI and arthroscopy has also been described.

Fissures should be stabilised using large transcondylar implants. Traditionally implants have been placed in a lateral to medial direction, but were associated with a high complication rate, up to 60%. Recently it has been suggested that placement of the screw in a medial to lateral direction may be associated with a decreased complication rate. To date biological techniques to stimulate healing of the HCF have not been shown to be universally successful, although research in this area is ongoing.

Surgical complications may include joint penetration by the screw, seroma formation, infection, late implant failure, osteoarthritis and persistent lameness. Seromas are usually best treated conservatively; infections can be treated by long courses of antibiotics +/- joint lavage +/- topical antibiotics +/- implant replacement or removal; implant failure is managed by implant replacement; OA and long-term lameness are usually treated medically. Complication rates can be minimized by use of large core diameter implants placed in a medial to lateral direction; precise surgical technique is obligatory.

**References**

Hattersley R, McKee M, O'Neill T, Clarke S, Butterworth S, Maddox T, Owen M, Langley-Hobbs SJ, Comerford E. Postoperative complications after surgical management of incomplete ossification of the humeral condyle in dogs. Vet Surg. 2011 Aug;40(6):728-33

Clarke SP. The humerus. In: BSAVA Manual of Small Animal Fracture Repair and Management, 2nd edition. Edited by Gemmill TJ and Clements DN. BSAVA, Cheltenham, UK. 2016

**11 Complex fractures of the distal humerus**

**Learning objectives**

At the end of this session, participants should be able to:

* Describe surgical approaches to the distal humerus
* Critically analyse and compare different fixation methods and strategies  
  when dealing with complex articular fractures or the distal humerus
* Explain in detail how to stabilise a Y/T intracondylar fracture of the humeral condyle
* Recognise complications and how to manage them

All articular fractures of the distal humerus in the dog are complex problems; the requirement for accurate anatomical reconstruction coupled with robust fixation in a location with complex regional anatomy and limited bone stock all present significant surgical challenges. Although uni-condylar fractures are the most common configuration, di-condylar (Y/T) fractures are the more complex and will be considered here.

There has been a progressive evolution in how these fractures have been managed. Exposure of the fracture was historically achieved using a caudal approach to the elbow by performing a trans-olecranon osteotomy. Postoperative complications associated with this osteotomy, including infection, fixation problems and loss of reduction, are not infrequent with one study reporting a 37% complication rate; such complications can both be challenging to manage and have a negative effect on functional outcome, and as such have largely led to the abandonment of this approach. A combined medial and lateral approach to the distal humerus and elbow as described by McKee and others (2005) is now preferred, allowing for internal fixation to be applied to both the lateral and medial aspects of the distal humerus, optimising use of the available bone stock.

**Medial approach:** A skin incision is made from the medial epicondyle to the mid shaft of the humerus. An incision of the deep fascia between the brachial artery and vein and the ulnar collateral vessels allows for exposure of the median and ulnar nerves, which run with the blood vessels but lie slightly deeper to them. Retraction between these neurovascular structures allows exposure of the distal humeral shaft and epicondylar region. More, but limited proximal exposure can be achieved, although great care needs to be taken to protect the neurovascular structures whilst mobilising them. Some elevation of the superficial pectoral and brachiocephalicus muscles is also required.

**Lateral approach:** A skin incision is made passing slightly caudal to the lateral epicondyle. It extends distally in the region of the proximal ulna. Proximally the incision can extend to the mid shaft of the humerus if required, being dictated by the fracture location. The lateral head of the triceps is exposed and the deep fascia is incised along the cranial aspect of the triceps muscle, extending distally over the extensor muscles. Retraction of the fascia cranially and the triceps caudally reveals the condylar region of the humerus. The radial nerve emerges distally between the lateral head of the triceps and the brachialis muscles. To expose the humeral condyle for a uni or di-condylar fracture elevation of the extensor carpi radialis muscle from the supracondylar ridge exposes both the bone and the underlying joint capsule. The joint capsule can be incised to expose the humeral condyle. To facilitate bone plate application in this region the approach can be extended proximally; retraction of the brachialis muscle and radial nerve cranially and the triceps caudally exposes the lateral aspect of the humeral shaft.

**NOTE: The extent to which the radial nerve is exposed and indeed visualised will be dictated by the fracture location. For a uni-condylar fracture the nerve is often not visualised, although if more proximal access is required e.g. for concomitant plate application, care needs to be taken to protect the nerve, both during dissection and retraction.**

Surgical repair encompasses two aspects, reconstruction and stabilisation of the articular surface using a transcondylar bone screw and restoration of the mechanical axis by reattachment of the articular surface onto the humeral shaft. There are two methods with which this can achieved; the decision is largely based on surgeon preference, although may be dictated by the fracture configuration.

* Humeral condyle reconstruction and stabilisation followed by re-attachment of the intact humeral condyle onto the humeral shaft (Ness 2009). The advantage of this method is that accurate reconstruction of the articular surfaces is given priority.
* Reduction and re-attachment of either the medial or lateral humeral condyle onto the humeral shaft followed by repair of the resultant uni-condylar fracture (McKee and others 2005). This technique is perhaps best suited to fracture configurations where a large supracondylar component is present.

Whether the medial or lateral aspect is reconstructed is dictated by the fracture configuration and preference of individual surgeon; however most often the medial aspect is stabilised first. The disadvantage of this method is that if the supracondylar region is not anatomically reconstructed perfectly it will then not be possible to anatomically reconstruct the resultant uni-condylar fracture, which will result in articular surface mal-alignment.

Ideally both the lateral and medial supracondylar regions should be stabilised using bone plates; either non-locking or locking fixation can be used. Distally it is important to be sure that the screws in the supracondylar ridge do not interfere with the anconeal process as they exit the trans-cortex and enter the supratrochlear foramen. If possible the most distal screws can be directed into the humeral condyle to increase bone /screw purchase. The use of non-locking screws / fixation allows flexibility in plate screw orientation which is often desirable in these fractures.

Despite the challenging nature of these fractures, experienced surgeons achieved good to excellent outcomes in ~ 90% of patients (McKee and others 2005, Ness 2009) with these methods. As with uni-condylar fractures some reduction in range of elbow joint and the development of osteoarthritis should be expected (Gordon and others 2003).

Achieving accurate anatomical articular surface reconstruction coupled with robust transcondylar and supracondylar fixation, applied via a combined lateral and medial approach are paramount in an attempt to achieve rapid restoration of limb function, minimise fracture disease and postoperative fixation complications. Robust fixation with offset the potential for long-term fixation failure where pre-existing humeral intracondylar pathology is present. Post-operative surgical site infection presents a challenge to manage; bone healing is generally achieved given the robust fixation, although bacterial infective arthritis can present a significant management challenge and result in a poor functional outcome.

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**12 Fractures of the proximal ulna**

**Learning objectives**

At the end of this session, participants should be able to:

- Describe options for stabilisation of fractures of the proximal ulna

- Explain the classification scheme for Monteggia fractures

- Identify methods of repair for Monteggia fractures

Fractures of the proximal ulna are overall uncommon and often result from significant trauma. They can be broadly categorized into olecranon fractures or Monteggia fractures.

Olecranon fractures can be classified as simple or comminuted, and extraarticular (proximal to the trochlear notch) or intraarticular (through the trochlear notch). The proximal fragment is often severely displaced proximally due to the distractive force of the triceps brachii muscle group. Open reduction and internal fixation is almost always warranted to counteract the pull of the triceps.

The proximal olecranon can be approached with a curved lateral incision between the lateral humeral epicondyle and olecranon. For the trochlear notch and proximal shaft, a caudal approach is made with the skin incision positioned slightly lateral or medial. The anconeus muscle and joint capsule is incised at the level of the medial coronoid process and radial head as needed to assess the articular surface. Fractures involving the joint surface should be repaired adhering to the techniques of articular fracture repair; anatomic reduction, rigid internal fixation, interfragmentary compression and early return to function. Extension of the elbow can facilitate fracture reduction.

Proximal extraarticular fractures can be stabilized with a pin and tension band to resist the distractive forces of the triceps. Two parallel k-wires are driven normograde or retrograde between the caudoproximal surface of the olecranon and the cranial ulnar cortex distal to the trochlear notch. A small (1.5-2.0 mm) hole is drilled transversely in the caudal aspect of the distal fragment and a figure-of-8 tension wire is applied using 0.8-1.25 mm orthopaedic wire. Care should be taken not to overtighten the wire as this will result in gap formation at the cranial cortex. The pins can be bent caudally, cut and rotated cranially to sit in small splits created within the triceps tendon of insertion.

Intraarticular transverse or short oblique fractures of the proximal half of the trochlear notch may be stabilized using either a tension band or a bone plate. Olecranon fractures in large or giant breeds, comminuted olecranon fractures and fractures in the distal half of the trochlear notch should be repaired using a bone plate and screws.

The ulna can be plated along either the caudal (tension surface) or lateral cortex. If applied caudally, the plate can be contoured over the olecranon, or less commonly a hook plate can be used. Care should be taken with the length of the screws so they do not penetrate the trochlear notch proximally or engage the radius distally. Application of a caudal bone plate may be impractical for several reasons, in which case the plate can be applied laterally. In smaller dogs and cats caudal plate application is challenging due to the narrow nature of the proximal ulna in this plane. Furthermore bone plate applied to the caudal aspect of the proximal ulna may result in pressure sore formation over the olecranon.

Monteggia fractures are fractures of the proximal half of the ulna with concurrent subluxation or luxation of the radial head. They occur due to a blow against the caudal ulnar surface during weight bearing. The radial head may luxate in any direction; cranial (type I, most common), caudal (type II) and lateral (type III). Type IV refers to fractures of both the radius and ulna with cranial luxation of the radial head.

If the annular ligament is intact, then reduction of the ulnar fracture will reduce the luxated radial head. The ulnar fracture can then be repaired with a normograde IM pin supplemented with coaptation (acute fracture in cats or small dogs), or more commonly a caudal bone plate and screws.

If the fracture of the ulna is distal to the coronoid processes or radial head then the annular ligament will have been disrupted. Simply suturing a torn annular ligament results in reluxation in one-third of cases. When the annular ligament has been torn, then the radial head should first be reduced and then the ulnar fracture stabilised. The radial head can be secured to the ulna with one or two screws placed from caudal to cranial. Radio-ulnar screw(s) will interfere with pronation and supination and may loosen prematurely; they may be removed 4-6 weeks post-operatively to allow normal movement to resume between the proximal radius and ulna. To overcome this limitation, a Tightrope technique has been described (Vallone and Schulz, 2011). External coaptation should be provided for 3-4 weeks post-operatively.

The prognosis for proximal ulna fractures is overall described as good to excellent, depending on the degree of articular cartilage damage, anatomic reduction and type of fixation.

**Key points**

**-** Simple extra-articular olecranon fractures may be repaired using a pin and tension band technique

**-** Intra-articular fractures of the proximal ulna are most often repaired using caudal or lateral bone plates. Closely adhering to the principles of articular fracture repair can result in good to excellent outcomes.

**-** Monteggia fractures are uncommon injuries. When the annular ligament is disrupted, fixation of the radius to the ulna is warranted.

**References**

Vallone L, Schulz K: Repair of Monteggia fractures using an Arthrex Tightrope system and ulnar plating. Vet Surg 2011:40;734–737.

**13 Complex fractures of the femoral head and neck**

**Learning objectives**

At the end of this session, participants should be able to:

* Recognise the mechanical and biological challenges present in this anatomical location
* Recognise the anatomical challenge caused by the lack of bone stock
* Explain in detail how to stabilise capital physeal and femoral neck fractures
* Discuss and select appropriate salvage options

Proximal femoral fractures may be, depending on location, intracapsular: epiphyseal, physeal, subcapital, or transcervical; or extracapsular: neck, intertrochanteric or subtrochanteric.

The small bone stock available for fixation in the proximal fragment, the intraarticular nature of some of the fractures, the anatomical particularities of the region and the disruptive forces acting constitute challenges when treating this type of fractures.

High-velocity injuries of the proximal femur present as intertrochanteric or subtrochanteric comminuted fractures. Low-velocity injuries dissipate less energy and normally result in two-piece fractures such as capital physeal fractures, femoral neck fractures or transverse fractures of the subtrochanteric region.

Different options of treatment can be used for proximal fractures of the femur. Complex fractures that cannot be repaired or failed attempts will require the use of a salvage procedure such as total hip replacement or femoral head and neck excision.

**References**

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**14 Juxta articular fractures of the distal femur and proximal tibia**

**Learning objectives**

At the end of this session, participants should be able to:

* Distinguish between distal femoral physeal and supracondylar fractures
* Recognise different fractures of the proximal tibia
* Select appropriate implants for fixation
* Describe how to stabilise distal femoral supracondylar fractures and proximal tibial fractures
* Anticipate challenges and complications

Distal femoral fractures account for 20-25% of all femoral fractures; of these roughly 30% are supracondylar fractures and 60% are physeal fractures respectively. Supracondylar fractures occur at the transitional zone between the diaphyseal cortical bone and epiphyseal cancellous bone; fractures can extend proximally and distally and can be comminuted. Chondrodystrophoid animals appear predisposed given their particular distal femoral anatomy.

Both physeal and supracondylar fractures require surgical management and it is critical to confidently differentiate between these fracture types as their differing mechanical and biological requirements necessitate different fixation techniques. In most cases, physeal fractures can be managed using adaptational osteosynthesis techniques. In contrast supracondylar fractures are most likely to occur in skeletally mature patients and as such require robust internal fixation. Supracondylar fractures can present many challenges, in particular the small fragment size for implant purchase, regional anatomy and their proximity to the stifle joint. A variety of fixation techniques have been described; most commonly these will employ bone plate fixation. The use of anatomic specific plates has helped circumvent the problems often faced when using conventional bone plates in this region, in particular they allow an increased number of screws to be placed in the distal bone fragment as well as avoiding the challenges of plate contouring. Locking plates can also circumvent this latter issue, although attention should be paid to screw trajectory to avoid articular surface violation; variable angle locking plates may be advantageous here. Attention should be paid to achieving accurate axial and rotational alignment of the fracture; discrepancy may result in patella mal-tracking. Robust fixation allows for early return to function and negates fracture disease. With appropriate fixation the prognosis should be good.

Juxta-articular fractures of the proximal tibia are most likely to occur in the skeletally immature patient and involve the physes resulting in either tibial tuberosity avulsion or tibial tuberosity and the proximal tibial epiphyseal separation. Such fractures generally result from low energy trauma and result in cranioproximal – caudodistal angulation of the proximal tibial plateau; such fractures are managed effectively using pin and tension band wire fixation. More uncommon, is to see a proximal tibial physeal fracture with a large metaphyseal component (Salter Harris 2) in which there is both marked displacement and marked instability of the entire tibial epiphysis (Clements and others 2009). Such fractures are more challenging to manage given their inherent instability. Management can be with rigid internal fixation or adaptational osteosynthesis; the relatively weak fixation provided with the latter may be augmented by lag screw stabilisation of the large metaphyseal fragment and/or temporary trans-articular external skeletal fixation (Clements and others 2009).

Rarely a proximal tibial metaphyseal fracture with a curvilinear configuration is seen in small breed dogs (Deahl and others 2017). Despite their innocuous appearance these fractures can be difficult to reduce accurately; they can be stabilised by a variety of fixation techniques, although internal fixation with a bone plate is desirable. Juxta-articular / metaphyseal fractures in skeletally mature patients are rare. Varying fracture configurations can occur; however comminution appears rare. Anatomical reconstruction with robust internal fixation is required; orthogonal bone plating is useful in this location to optimise screw purchase in an often-small proximal bone fragment, which is generally subjected to marked distractive forces from the quadriceps mechanism. When comminution is present the plate may be required to act as a true buttress plate to shore up the articular surface. Managed appropriately the prognosis is good in most cases. Implants, particularly in the region of the tibial tuberosity can cause patella tendon irritation and necessitate removal. Failure to achieve accurate reduction may result in malunion, which may be of functional significance. Any resultant proximal tibial deformity, which leads to an increase in tibial plateau angle, may be a contributing factor in the development of future cranial cruciate ligament disease. Deformity in the mediolateral plane would be a greater concern.

**References**

Clements DN and others (2009) Management of laterally displaced proximal tibial physeal fractures in three dogs. JSAP 50, 662-666

Deahl and others (2017) Proximal tibial metaphyseal fractures in immature dogs. VCOT 30:237-242

**15 Distal tibial fractures**

**Learning objectives**

At the end of this session, participants should be able to:

* Recognise the biological and mechanical challenges present in this anatomical location
* Compare and contrast different fixation strategies including combining implants
* Describe in detail how to stabilise a complex fracture of the distal tibia
* Anticipate complications

Malleolar fractures invariably involve the articular surface affecting the origin of one of both portions of the collateral ligaments. Malleolar fractures can be classified as unilateral, bilateral or bimalleolar and trimalleolar when they involve also the third malleolus located in the posterior aspect of the tibia. Fractures involving the medial malleolus tend to result in variable degrees of valgus deformity, whereas fractures of the lateral malleolus permit a varus deformity.

Careful clinical examination with flexion and extension of the talo-crural joint, allows the evaluation of the short and long ligament components.

The radiographic examination should include standard DP, Lateral views and oblique views. Additional medial and lateral stressed views are often necessary in order to evaluate the degree of subluxation and the size of the avulsed fragment.

As malleolar fractures involve articular surfaces, open reduction and internal fixation are the golden standard. Fractures of the medial and lateral malleolus are usually repaired with K wires and figure of eight tension band wire, via medial and lateral approaches. Occasionally, in case of large fragments of the medial malleolus or when a significant length of the distal fibula is involved, it is possible to use lag screws and anti rotational K. wires.

**Lateral malleolus**

The lateral malleolus is the distal part of the fibula. In the canine species this bone is very thin and IM pinning and application of a tension band in the very bone is much more of an artistic license rather than a practical possibility. In the dog the small K wires or the mini lag screws are inserted from the malleolus to the adjacent tibia achieving an indirect repair of the fracture. The K wires or screws should engage the far cortex of the tibia to guarantee optimal holding power.

The cerclage wire should pass thought a tunnel in the tibia rather than in the thin fibula. Most common pitfalls are incorrect reduction of the fracture and violation of the joint. To avoid this complication, it is very important to assess the fracture reduction and evaluate joint congruity in flexion and extension while inserting the K. wires or screws at a correct angle.

**Medial malleolus**

The medial malleolus is the distal part of the tibia. Fractures of the medial malleolus can involve both the long and short portions of the collateral ligament origin. In this case the fragment is usually quite large and allows the placement of two K wires and a figure of eight tension band wire or a lag screw.

Unfortunately if is only the origin of the short component to be involved, the repair of this fracture avulsion can be quite demanding. The fragment is usually too small and very difficult to reduce due to the overlapping of the long portion of the ligament. Use of mini Gelpi retractors, a combination of flexion and intra rotation of the joint and patient manipulation of the fragment will help to achieve a successful repair. The cerclage wire should pass under the ligament, and around the tips of the K wires, to avoid irritation of the long component of the ligament.

Common pitfalls are invasion of the joint space due to incorrect orientation of the K wires, cyclic failure of the tension band wire due to incorrect placement and non union of the fragment due to lack of reduction.

**Post operative care**

The repair of these fractures is quite tenuous and needs a strong post operative support in the form of a fiberglass cast or lateral/medial splint for at least 4 weeks. Cage or kennel confinement is recommended for hyperactive dogs until cast removal.

In case of bimalleolar or trimalleolar fractures it might be necessary to apply a transarticular external fixator to support the repair for 5 to 8 weeks.

**Fractures of the third malleolus**

Fractures of the third malleolus are described as an axial slab of the triangular posterior portion of the tibial cochlea. These fractures are usually associated with bimalleolar fractures and rarely are described as a solitary injury. Although trimalleolar fractures have been described by Montavon, Dee et al in racing Greyhounds, this injury is not limited to working dogs and has been reported in other breeds. With incomplete fractures, the history and clinical signs can be quite subtle. The dog is generally lame after mild exercise but usually weight bearing. The lameness is typically self-limiting to 24 to 48 hours. Clinical examination reveals swelling affecting the caudo-medial aspect of the distal tibia, directly over the joint. Pain during direct palpation and with hyper flexion of the talo-crural joint are also consistent findings. When a complete fracture is present the clinical signs are more dramatic. The dog is generally lame and non-weight bearing on the limb, diffuse swelling is present around the joint, and pain with flexion and extension are almost constantly detectable. Radiographic examination consists of standard dorso-plantar or plantaro-dorsal, medio-lateral, and oblique views. The medio-lateral hyper flexed view is usually diagnostic and necessary to evaluate this type of fracture. Open reduction and internal fixation with lag screws, and if required an anti-rotational K-wire, is the treatment of choice. The surgical approach is directly over the lesion. The screw head is countersunk to avoid interferences with the surrounding soft tissues and bony structures. Postoperative care consists of application of a padded bandage for 10 days and cage or kennel confinement. A regimen of gentle physiotherapy is initiated after suture removal. Following four weeks of rest and radiographic evidence of bone healing, controlled activity is allowed and sporting dogs are reintroduced to gradual training. Prognosis is usually good to excellent.

Some selected cases of incomplete and chronic incomplete fractures can be treated conservatively with external coaptation and cage rest. However, this treatment is reserved for non-athletic dogs.

**Catastrophic fractures of the distal tibia**

A pilon fracture can be defined as a metaphyseal injury extending to the tarso-crural joint. These fractures can be generated by low energy trauma (e.g. running and jumping) or by high energy trauma (e.g. fall from a height or road traffic accident). The nature of the trauma usually influences the complexity of the injury, the degree of comminution, and the soft tissue involvement. Pilon fractures are extremely difficult to treat by any method. A combination of techniques and implants are usually necessary. Initial reconstruction is started with reduction of the fragments using K-wires and figure of eight tension band wires. Lag screws and L or T plates are usually used to complete the fixation. The outcome depends on the quality of the articular reconstruction and on the soft tissue conditions. Due to their complexity, it is often difficult to achieve satisfactory stability of these fractures; therefore, allowing only partial weight bearing and addition of extra support to the repair is a necessity. Transarticular external fixation, either linear or hybrid, offers the best option. In selected cases use of external coaptation as a functional cast is an alternative choice. Unfortunately, the amount of comminution is sometimes technically overwhelming and a pan-tarsal arthrodesis becomes the only choice. The key for successful treatment is adequate planning, training, instrumentation, postoperative care, and physiotherapy. The most common complications include: implant failure due to inadequate fracture stabilization or excess of early motion; ankylosis of the joint due to prolonged immobilization; osteoarthrosis; and vascular damage due to excessive surgical exposure and inappropriate soft tissue handling during the procedure.

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**16 Diagnostic approach to carpal instability**

**Learning objectives**

At the end of this session, participants should be able to:

* Describe the normal motion of the carpus
* Explain the most common causes of carpal instability
* Demonstrate an understanding of diagnostic strategies to aid with decision-making in carpal instability

The carpus is a composite joint, with primary joint motion in flexion and extension. The antebrachiocarpal (ABC) joint, between the radius and ulna and the proximal row of carpal bones, accounts for 70% of carpal motion. The middle carpal joint, between the proximal and distal rows of carpal bones, accounts for 25% of carpal motion. The carpometacarpal (CMC) joint, between the distal row of carpal bones and the bases of the metacarpal bones accounts for only 5% of carpal motion. The carpus also demonstrates a minor amount of internal and external rotation, a few degrees of varus-valgus and several millimetres of translation in the dorsal-palmar plane. During the stance phase at trot, the ABC joint angle has been reported to peak at 24 degrees (Garcia et al, 2014). However, the physiologic limits of carpal extension can be much higher when under stress; for example, when entering any angle A-frame the mean carpal extension angle reaches 62 degrees (Appelgrein et al, 2017).

The dorsal ligaments of the carpus are thin compared with the palmar ligaments. The palmar ligaments converge with the palmar fibrocartilage, providing robust support to the palmar surface of the joint, which is under near constant tension. The collateral ligaments span only one joint level and are strong, in particular the medial collateral ligament, which is under near constant tension due to normal physiologic valgus. The medial collateral ligament has straight and oblique components in dogs, with just the oblique component present in cats.

Conditions resulting in carpal instability may include traumatic hyperextension injury, rupture of the collateral ligaments, luxation and fracture. Traumatic disruption of the medial and lateral collateral ligaments of the carpus is rare in pet dogs. Chronic lateral collateral ligament sprain resulting in carpal varus has been described, primarily affecting older Dobermans (Langley-Hobbs et al, 2007)

The most common condition affecting carpal stability is hyperextension injury with disruption of the palmar fibrocartilage, flexor retinaculum and palmar ligaments. Carpal hyperextension injury most commonly occurs following jumping or falling from a height, although atraumatic aetiologies have been reported. Carpal hyperextension injury may affect any of the ABC, intercarpal or CMC joints in isolation or concurrently. The distribution of the level of disruption has been described as 31% affecting the ABC joint, 22% affecting the middle carpal joint and 47% affecting the CMC joint (Parker et al, 1981). The ABC joint is reported to be affected in 50% of cats. If it can be established that the supporting structures of the ABC joint have not been disrupted then partial carpal arthrodesis may be considered. Partial carpal arthrodesis retains motion of the ABC joint during gait, with 76 degrees or 50% of carpal flexion maintained (Andreoni et al, 2010).

The patient should initially be assessed in a standing position; the carpal extension angle and any varus-valgus angulation are compared bilaterally. The carpus should be carefully palpated in all planes to assess for carpal bone subluxation, fracture, collateral ligament stability and dorsal and palmar stability. The range of motion and the location and degree of any soft tissue swelling or peri-articular fibrosis should be noted. In grade 1 or 2 sprains of the collateral ligaments, it is unlikely that instability will be palpable.

Standard orthogonal radiographs (dorsopalmar and lateral) should be obtained. Stress projections should include dorsopalmar views with application of medial and lateral stress to assess for collateral instability, as demonstrated by widening of the joint space. Dorsally stressed lateral views are useful to assess for palmar instability. The author has found standing radiographs very helpful to identify the location of disruption in cases of carpal hyperextension injury. Carpal bone fractures can be difficult to identify on standard radiographs. CT is helpful to identify subtle fractures and for surgical planning for complex fractures.

Advanced imaging techniques (CT, MRI, CT arthrogram and MR arthrogram) were recently assessed for visualization of carpal ligaments and tendons in normal cadaveric specimens (Castelli et al, 2017). CT arthrogram and MR arthrogram were found to improve the visibility of specific soft tissue structures. These techniques will likely become standard for assessment of soft tissue injuries in the future, however rely on the availability of high resolution technology (3.0 T magnet).

**Key points**

**-** Carpal hyperextension injury is the most common cause of carpal instability

**-** Identifying the level of disruption is key for decision-making

**-** Careful palpation and stressed radiographs are useful aids to assess carpal stability

**-** Advanced imaging techniques will likely become more widely used in the future

**Key References**

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pancarpal arthrodesis in dogs. Vet Comp Orthop Traumatol 2010;23:1–6

Appelgrein C, Glyde M, Hosgood G, Dempsey A: Measurement of carpal joint extension in agility dogs entering the A-frame. Proceedings of the 26th Annual Scientific Meeting of the European College of Veterinary Surgeons, Edinburgh, UK, 2017

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**17 Pancarpal arthrodesis – surgical technique**

**Learning objectives**

At the end of this session, participants should be able to:

* Revise the principles of arthrodesis
* Discuss the advantages and disadvantages of dorsal plating versus medial or bi-axial plating in PCA
* Understand the indications for PCA
* Learn how to perform a PCA using a dorsally applied plate
* Learn to anticipate challenges and complications

Canine carpal arthrodesis is most commonly indicated as a treatment for carpal hyperextension. Injury can occur as a result of trauma or because of developmental or idiopathic degeneration of the palmar carpal ligamentous support and palmar carpal fibrocartilage. Other reasons for carpal arthrodesis include carpal fractures or dislocations, erosive immune-mediated arthritis, end-stage osteoarthritis, chronic septic arthritis, or as a treatment for selected cases of radial nerve paralysis.

PCA planning can be approached in a similar fashion to fracture repair planning. Important preoperative considerations include biological, mechanical, and clinical factors. Biological factors are frequently unfavorable due to the paucity of soft tissue cover and a lack of endosteal blood supply. Consequently, prolonged fusion times should be expected, and for this reason, durable internal fixation is preferred to external skeletal fixation in the vast majority of cases, as the latter is prone to premature implant loosening prior to completion of arthrodesis.

*Surgical approach:* Various patterns of skin incision have been described to allow this goal to be achieved. The surgical incision should not be directly over the planned location of the plate and screws, as this can compromise subsequent skin healing.

*Cartilage debridement:* Low-torque high-speed burrs are the author’s choice for cartilage debridement, although it is possible to achieve debridement with small bone rasps, curettes, and osteotomes.

*Bone grafting:* Cancellous bone is harvested from the proximal humerus. Various bone graft substitutes have also been used to facilitate timely arthrodesis. Placing the bone graft before plate fixation allows more complete access to all areas of the carpal joint spaces.

*Plate and screw fixation:* Multiple implant options are available, including:

1. DCP, LCP and veterinary cuttable plates (toy breed dogs)
2. Hybrid PCA plate (hPCA)
3. CastLess plates (Orthomed)
4. Stepped arthrodesis plates (Synthes)

Plate and screw positioning options include dorsal, medial, palmar, biaxial and plate-crosspin constructs.

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Clarke SP, Ferguson JF, Miller A Clinical evaluation of pancarpal arthrodesis using a CastLess plate in 11 dogs. Vet Surg 38(7): 852-60, 2009

**18 Intertarsal arthrodesis**

**Learning objectives**

At the end of this session, participants should be able to:

* Formulate a diagnostic plan when dealing with intertarsal instability
* Recognise when a salvage option is required
* Explain how to perform a partial tarsal arthrodesis (lateral plating)
* Anticipate challenges and complications

The inter-tarsal region is a complex composite of low motion joints supported by a myriad of different ligamentous structures. Intertarsal stability and thus distal limb posture is maintained by a strong plantar ligament complex on the tension aspect, whilst dorsally on the compression aspect, the requirement for such robust ligament support is unnecessary. A variety of ligaments provide both lateral and medial intertarsal stability. Instability can originate at different intertarsal joints; common locations include the proximal intertarsal joint, centrodistal joint or tarsometatarsal joints. From a diagnostic perspective the two most important factors are to determine are the joint(s) at which the instability is originating and what supporting ligamentous structures are damaged; both dictate what management will be required. Thorough clinical and radiographic assessment (the latter may require stressed projections) is paramount to obtain both an accurate diagnosis and to allow appropriate decision-making.

Intertarsal arthrodesis is well tolerated, having no impact on either limb posture or function, given the inherent low motion nature of these joints. The requirement for intertarsal arthrodesis is absolute when there is loss of plantar ligament support; the development of fibrous tissue to provide adequate plantar support, by some other means, should not be relied upon. Arthrodesis is this situation should be achieved instability, but where plantar ligaments are intact, immobilisation of the affected intertarsal region, ideally with internal fixation but without cartilage removal, is likely to be sufficient i.e. fibroplasia is likely to provide adequate support; it is also assumed that intertarsal joints may achieve ankylosis. Limited articular cartilage debridement +/- bone grafting, are still appropriate to consider in these situations, and are performed by this author. The use of pins, screws and orthopaedic wire are often reported in these situations, however the use of an appropriate bone plate will provide more robust, reliable fixation whilst negating the requirement for any adjunctive external coaptation.

Proximal intertarsal joint or tarsometatarsal joint arthrodesis are most commonly performed using a laterally placed bone plate, secured to the calcaneous, 4th tarsal bone and metatarsal region. Attention should be made to the following:

* Appropriate plate selection
* Appropriate skin incision location
* Appropriate plate contouring / bone sculpting
* Thorough articular cartilage debridement and bone graft placement
* Appropriate screw placement within the metatarsus – the key to success
* Tension free skin closure

Lateral bone plate application remains a technically challenging procedure; unfortunately errors in technique and application remain the most likely reason for postoperative complications and / or poor limb function.

**References**

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**19 Talocrural arthrodesis**

**Learning objectives**

At the end of this session, participants should be able to:

* List indications for pantarsal arthrodesis (PTA)
* Select appropriate implants for fixation
* Describe how to perform PTA using a medial or lateral plate
* Anticipate and manage challenges and complications

PTA is a salvage procedure used to manage severe conditions affecting the talocrural joint. Good outcomes can be achieved, however the risk of intraoperative or postoperative complications is relatively high. Indications for PTA include:

- Joint trauma with significant bone loss

- Severe intra-articular fractures

- Severe talocrural osteoarthritis

- Degenerative or recurrent Achilles tendinopathy

- Revision of failed primary surgery

The talocrural joint is subject to large bending forces which must be neutralized. Options for stabilization include dorsal or medial plating; lateral plating can also be considered, but this is less straightforward than medial plating and is rarely performed.

Because the dorsal aspect of the talocrural joint is in compression, dorsally applied plates are subject to large bending forces which can result in implant failure. Application of the plate to medial aspect of the joint allows the plate to be loading ‘on edge’. This increases its AMI, giving a more mechanically robust construct.

The surgical approach to the medial aspect of the tarsus is straightforward, and avoids vascular structures on the cranial or caudal aspect of the joint. In addition, application of a pre-contoured medial plate following removal of articular cartilage is helpful in maintenance of limb alignment.

The soft tissue coverage of the tarsus is poor. This can contribute to complications such as infection, and therefore strict aseptic technique is essential. Excessive soft tissue tension during wound closure can lead to wound dehiscence and avascular necrosis of the distal limb. Soft tissue tension can be managed by use of releasing incisions; these are left to heal by secondary intention.

Anatomic plates are used with a thickened region centrally. This increases the AMI of the plate to reduce risk of plate breakage. Plates come in various sizes to accommodate different sized patients. The angle of the plate varies from 120 degrees for smaller plates up to 140 degrees for larger plates.

In all case the principles of arthrodesis should be applied, including:

- Removal of all articular cartilage

- Stabilisation at a functional angle

- Rigid fixation

- Bone graft

The patient is placed in lateral recumbency with affecting limb dependent, A caudomedial skin incision is made, and a medial approach made to the joint. Proud bone from medial aspect of the tarsus is removed, down to the level of the medial trochlear ridge of the talus. A plate is then contoured to the medial aspect of the limb, and screws placed in the talus and proximaly and distally in the tibia and the metatarsus. The plate is then removed and all cartilage from the talocrural joint debrided using a burr; if desired the medial aspect of the subtalar joints is also debrided. Following application of a bone graft the pre-contoured plate is re-applied and the remaining screws placed. An additional talocalcaneal or tibiocalcaneal screw can also be placed. The soft tissue is then closed routinely, taking great care to avoid tension on the wound.

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**20 Sacroiliac fracture luxation**

**Learning objectives**

At the end of this session, participants should be able to:

* Evaluate options for management of sacroiliac fracture-luxation in cats and dogs
* Critically analyse and compare sacroiliac lag screw versus combination fixation (lag screw plus transilial pin)
* Describe the clinical implications of a sacral fracture versus a sacroiliac fracture-luxation

The sacroiliac joint has both synovial and cartilaginous components, including cartilage-covered surfaces, a joint capsule, and dorsal and ventral ligaments. There is little natural movement at this joint and surfaces may become fused with age in some dogs. Given the anatomical design of the pelvis unilateral sacroiliac luxation cannot occur in isolation, instead it is associated with pelvic floor or contralateral hemi-pelvic factures; less commonly bilateral sacroiliac luxation occurs. Concomitant neurological injures can also be present.

When indicated surgical stabilisation restores the weight bearing axis, optimises pelvic canal diameter, improves patient comfort and should provide both a more predictable and quicker patient recovery. Sacroiliac stabilisation is most commonly and reliably achieved with direct stabilisation; most commonly a lag screw and less commonly with a transiliosacral bolt or pin. Alternatively indirect stabilisation using transilial fixation can be used as the sole form of fixation or as an adjunct to direct stabilisation, in an attempt to improve stability. Direct stabilisation techniques can be facilitated using fluoroscopy to aid reduction and sacral implant placement allowing these to be achieved using a minimally invasive osteosynthesis technique.

It should be remembered that many patients are likely to have concomitant orthopaedic and neurological injuries, which may have an influence on the overall functional outcome of the patient. As such reports of differing techniques report outcome measures, which include such things as: implant location, loosening, depth of sacral penetration, reduction achieved, maintenance of pelvic canal diameter in order to report their effectiveness.

With lag screw and trans-sacral pin/bolt placement the greatest surgical challenge is ensuring accurate placement of the implant within/across the sacral body; a comprehensive knowledge of the surgical anatomy of the sacroiliac joint is imperative. With unilateral lag screw fixation a depth 60% of the sacral body must be achieved to negate against the risk of screw loosening.

In the dog the starting point for the drill hole within the sacral body is established by projecting a line between the craniodorsal aspect of the sacral wing and the ventral aspect of the articular surface; the hole is drilled just caudal to this line, approximately 40% from the ventral limit of the sacral wing. When present the sacral notch in the cranial aspect of the sacral wing it serves to confirm the surgeon’s estimation of the sacral body location; the start point should be just caudal to this notch. A drill angle of 97° from the articular surface in the dorsoventral plane has been recommended to avoid penetration of the neural canal but still achieve a drill hole 65% of sacral body width. In contrast inter-patient variation in sacral anatomy means a generic drill angle recommendation with respect to the sacral articular surface in the craniocaudal plane cannot be given; suitable angle estimation should be made from preoperative radiographs assessment.

In the cat the start point for the drill hole within the sacral body is ' 51% of sacral wing length and ' 47% of sacral wing height. The start point is still just cranial to the semi-lunar synovial part of the joint. In comparison the articular surface of the sacral wing in cats is positioned more cranially and ventrally with respect to the sacral body than in the dog. The sacral notch is not a useful landmark in the cat with respect to the start point. Drill orientation from the start point in the dorsoventral orientation should be at 90° (+/- 2-4°) to the articular surface of the sacral wing. This avoids neural canal penetration; risk of ventral penetration remains (35-58%) but at ' 66% of sacral body width. The ventral aspect of the sacrum can be palpated with a blunt instrument to guide the most appropriate drill angle.

Although challenging, placement of a second shorter lag screw dorsal and cranial to the first can be considered; an in vitro biomechanical study of sacroiliac screw fixation reported that two screws placed for sacroiliac fixation were always stronger than one screw. Most commonly a single screw is placed; using the largest screw possible optimizes fixation strength.

With lag screw placement the prognosis is good to excellent in the majority of patients; achieving screw purchase within at least 60% of sacral body width is imperative to provide stable lag screw fixation.

Bilateral luxations can be managed using bilateral lag screws; alternatively a single transiliosacral screw, bolt or pin can be used. Where a single implant is used for bilateral stabilisation an approach to each side allows for the “start” point to be identified on the sacral articular surfaces and use of an aiming device allows for accurate trans-sacral drill hole placement.

Indirect stabilisation with transilial pinning removes the requirement for sacral body screw placement, reducing the surgical challenge. However, in the dog, finite element analysis has shown that when used as the sole method of fixation, it is less rigid compared to lag screw fixation. Transilial fixation is most commonly achieved using pins; rarely a transilial plate, bolt or screw may be applied. In the dog implant loosening has been reported as a not infrequent occurrence with transilial pin placement; despite this a good to excellent outcome was reported in 92% of dogs in one study. Given its propensity to loosening, its use in dogs, as a stand-alone technique, likely needs to be weighed against the potential for morbidity in the postoperative period, which could impede recovery. In cats’ transilial fixation resulted in a good clinical outcome in cats with unilateral sacroiliac luxation. A good functional outcome was also reported for lag screw fixation combined with transilial fixation.

On occasion detachment of the ilium form the sacrum is associated with a sacral fracture (type I or II); pain is often marked and neurological deficits can be significant, in particular with Type II fractures, which traverse the sacral foraminae. The presence of a sacral fracture may result in loss of the normal anatomical landmarks used to ascertain the start point for the sacral drill hole; as such direct stabilisation using a lag screw may be challenging, although intra-operative fluoroscopy can aid with this. Alternatively, indirect stabilisation using transilial fixation or vertebral body/ilial screws and/or pins and PMMA can be used.

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Bowlt KL, Shales CJ. [Canine sacroiliac luxation: anatomic study of the craniocaudal articular surface angulation of the sacrum to define a safe corridor in the dorsal plane for placement of screws used for fixation in lag fashion.](https://www.ncbi.nlm.nih.gov/pubmed/21077923) Vet Surg. 2011 Jan;40(1):22-6

**21 Fractures of the ilium**

**Learning objectives**

At the end of this session, participants should be able to:

* Recognise the variety of fracture configurations and mechanical challenges present in this anatomical location
* Formulate and justify a management plan for a ilial fractures
* Explain in detail how to stabilise an ilial fracture with a plate
* Recognise the benefits of using locking implants in this location

Fractures of the pelvic ring are always multiple, affecting several parts of the pelvic bones, and are usually combined with sacroiliac luxations. The indication for surgical intervention in pelvic fractures are narrowing of the pelvic canal and/or ilium fracture instability with weight bearing compromise. Surgical repair is always indicated in acetabular fractures. If sacroiliac luxation is evident, there is need for surgical repair when the luxation is bilateral, or if the dislocation in the worst affected side implies more than 50% of the articular surface and is accompanied by an iliac or acetabular fracture. Other pelvic bones (pubis, ischium or pelvic symphysis) might be fractured, but surgical repair is not necessary unless the fragments narrow excessively the pelvic canal. Preoperative neurological assessment is important as sciatic nerve deficits are frequently found after pelvic fractures. To avoid iatrogenic nerve damage, oscillating drilling mode has been recommended during drilling the ilium.

Fracture of the ilium can be stabilized with plates and screws. At least 2 screws per fragment are needed. The ventral border of the bone is thicker and provides better screw purchase. To increase stability, some of the cranial screws can be positioned in the sacrum. In case of oblique fractures, they can be stabilized with lag screws or k-wires and figure 8 cerclage; concurrent placement of a neutralisation plate is advised, if possible.

**References**

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**22 Acetabular fractures**

**Learning objectives**

At the end of this session, participants should be able to:

* Analyse treatment options for acetabular fractures
* Describe the surgical approach to the acetabulum
* Critically analyse different fixation options
* Explain in detail how to stabilise an acetabular fracture with a reconstruction or locking plate
* Anticipate challenges and complications

Acetabular fractures account for approximately 12% and 7% of pelvic fractures, respectively. The majority of these injuries are caused by road traffic accidents, resulting in multiple injuries to approximately 40% of dogs and almost 60% of cats.

As in all trauma cases, the essentials of airway, breathing, and circulation are the initial priorities for a patient with an acetabular fracture, followed by a secondary survey. The latter is mandatory, as these high-energy fractures are frequently associated with other pelvic ring and long-bone fractures. They are also associated with thoracic and abdominal visceral injuries which are often severe in themselves.

Even though injuries to the sciatic nerve are more commonly associated with iliac fractures or sacroiliac joint fracture-luxations, they do occur with acetabular fractures and a careful neurological examination is essential. To minimize the risk of secondary arthrosis, early reconstruction of the hip joint is desirable.

Radiographs in at least two planes are required to decide whether surgery is indicated and what procedure to employ. The ventrodorsal projection provides an initial overview of the topography of the pelvic injuries. A lateral oblique projection, in which the patient is positioned with its injured hip joint on a foam wedge at an angle of 20–30º, permits separate assessment of the two halves of the pelvis. The fractured acetabulum that is closest to the radiographic plate, particularly its weight bearing dorsal area, is visualized above the contralateral acetabulum in such a way as to allow the fracture line(s) to be seen without difficulty. In exceptional cases, a mediolateral view can provide useful additional information. If available, computed tomography (CT) transverse sections, with 3-D reconstruction, allow a better appreciation of the fracture orientation and make it easier to plan the position of the implants correctly

Acetabular fractures have been classified as cranial, central, and caudal. Since the cranio-central area has been historically believed to be the weight-bearing zone of the acetabulum, fractures in this area are normally considered the most significant in functional terms. Caudal fractures can be associated sometimes with mild clinical signs and are often treated conservatively although this will result in secondary arthrosis with conservative management.

**Indications for surgery**

Surgical intervention is indicated when acetabular fragments are unstable or displaced. However, surgery will only be of long-term benefit if the joint is anatomically aligned and completely stable. If these goals are not attained, surgery is a costly procedure of dubious value. Normal joint mechanics can only be achieved through accurate reduction leading to a congruent joint. On the other hand, poor reduction or subluxation of the hip joint will lead to abnormal stresses acting on the articular cartilage and subsequent arthrosis. Indeed, even where acetabular fractures have been reconstructed correctly, degenerative changes can still occur due to the damage caused to the articular cartilage at the time of the injury. Nevertheless, the progression of arthrosis can be minimized if anatomical conditions are restored.

**Surgical Approach**

Normally the surgical approach will involve osteotomy of the greater trochanter. This is preferable to gluteal tenotomy, which generally has a poorer record of healing. Moreover, it can be per - formed in young animals, since growth retardation of the greater trochanter poses no problems. I have used Glureal tenotomy in cats with no problem. I have use this approach as well in a pug puppy with no issues. In cats, with cranial acetabular fractures is possible to fix them via a conventional cranio-lateral approach to the hip.

**Transverse fractures**

Transverse fractures, the majority of which run through the center of the acetabulum, are more difficult to reposition than oblique fractures. Reduction techniques consist of a combination of traction, leverage, and rotation. The femur can be used to aid repositioning, by elevating the caudolateral portion of the origin of the vastus lateralis muscle from the bone and attaching reduction forceps below the greater trochanter. Or by placing a reduction forceps around the greater trochanter. Care should be exercise to ensure we don’t injure the sciatic nerve.

The caudal acetabular fragment which is normally tilted caudally may be manipulated back into position, either by means of a second pair of reduction forceps applied to the ischium, taking care to avoid stretching the sciatic nerve, or by using a Steinmann pin inserted caudally through the skin into the ischium.

Once the reduction is stablished, a K-wire drilled across the fragments, using either the cranial or the caudal approach depending on the position of the fracture line, can be useful to aid reduction. If it proves impossible to f x the fragments in their correct position using the pointed reduction forceps, as frequently tends to be the case, a pre-contoured plate can be applied in order to facilitate repositioning. This is technically very challenging. If the plate is not perfectly contoured it will disturb the reduction when the screws are tightened.

For this very reason I tend to use locking acetabular place when possible to maintain the reduction. In some cases it is possible to reduce the fracture with screws and cerclage wire. If this method is used I would recommend augmentation with additional screws and bone cement.

**Combined ilial and acetabular fractures**

Depending upon the position of the fracture line, combined acetabular and ilial fractures may be stabilized using either two plates, eg, the C-shaped acetabular plate and a straight plate for the ilium, or a long reconstruction or locking plate, contoured to span both fracture.

**Comminuted fractures of the acetabulum**

Historically, Comminuted (> 3 fragments) acetabular fractures involving the ilium and ischium lend themselves to fixation using a long reconstruction plate anatomically contoured to the hemipelvis. Reconstruction plates using 2.7 mm screws for medium-sized and large breeds of dogs and DCPs with 2.0 mm screws and miniplates with 1.5 mm screws for small dogs and cats. I found this approach very technically challenging and my approach is to reduce the fracture sequentially and applying temporary k-wires to maintain the reduction between the fragments. Once the fracture is reduced I use a locking acetabular plate or a polyaxial reconstruction-type locking plate.

**Prognosis**

The long-term prognosis following acetabular fractures essentially depends on the anatomical reconstruction of the articular surface. In an investigation of 87 dogs re­examined clinically and radiographically after a mean period of 3 years following conservative management, a 50% frequency of lameness was recorded. For 29 cats treated at the same clinic and followed up after an average of 2 years, this figure was 10%. In dogs, the frequency of arthrosis was 100%, whilst in cats it was 75%. However, the cats that were arthrosis free had fractures that did not involve the roof of the acetabulum.

After surgical treatment of acetabular fractures, the reported frequency of arthrosis ranges between 60 and 90%, whilst the frequency of lameness ranges between 20 and 40%. The majority of the follow-up examinations occurred between 6 months and 3 years. The longest observation period was in a study which followed up 34 dogs and 14 cats an average of 6.5 years after surgery. In this investigation, 29 dogs (85%) and 11 cats (79%) had coxarthrosis. Lameness was evident in 13 dogs (37%) but not in a single cat. Of these patients, 31% showed muscle atrophy of the operated limb. Thus surgically reconstructed acetabular fractures would appear to have a better prognosis than those managed conservatively, but it is nevertheless not an extremely good prognosis.

**References**

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**23 Managing orthopaedic infections**

**Learning objectives**

At the end of this session, participants should be able to:

* Describe the aetiology of osseous and articular infections
* Select diagnostic tests to characterise infections
* Formulate management plans; anticipate challenges and complications
* Describe the importance of stability in managing orthopaedic infections

Osteomyelitis is an inflammatory condition of bone typically caused by an infectious agent. Fungal infections are occasionally seen in tropical environments; however, the most common aetiology in the UK is bacterial infection.

Osteomyelitis is classified based on the route of infection (i.e. haematogenous, extension from surrounding tissues or direct inoculation during trauma) and the timescale over which it develops (i.e. acute or chronic).

Normal bone is highly resistant to infection and successful colonisation requires several key factors:

* Contamination with a sufficient quanitiy of bacteria
* Compromised bone blood supply (trauma/aggressive surgical technique)
* A favourable environment for bacterial growth (necrotic tissue/dead space/foreign material/instability)
* Comorbidities that increase risk include diabetes, hyperadrenocorticism and concurrent infection (pyoderma, cystitis, etc)

Acute osteomyelitis typically develops within three weeks of trauma or surgery and is typified by the classical signs of pain, swelling and heat of the fracture/surgical site and poor limb function. Chronic osteomyelitis take months to develop and may be associated with more subtle changes e.g. a poorer than expected limb function and progression of radiographic changes suspicious for the disease.

Radiographic changes to bone tend to be visible after 2 weeks and can include:

* Lysis around implants
* Periosteal new bone
* Sclerosis
* Cortical thinning
* Delayed/non-union
* Sequestra (rarely)

There are two overlapping principles of management.

1. Elimination of Bacteria

* Antibiotics (based of culture and sensitivity)
* Removal of the biofilm (removal of implants)
* Up to 60% of bacterial osteomyelitis cases are caused by *Staphylococcus* spp. (*S. intermedius* is most common). Empirical treatment with amoxicillin-clavulanic acid or cephalosporins pending bacterial and fungal C&S results is indicated. Metronidazole can be added if there are concerns regarding anaerobes.

2. Environmental control

* Debridement of necrotic tissue
* Stabilisation of the fracture
* Removal of redundant implants

Chronically infected implants are often coated with a thin layer of microorganisms within an adherent organic polymeric film known as a biofilm. Removal of the implant(s) and the associated biofilm usually effects prompt relief of the clinical signs.

Instability (inadequate fixation or implant failure) perpetuates and promotes infection due to persistent interruption of bone healing and revascularisation. Ensuring stability is critical to regaining control of the environment. Fractures will heal in the face of infection provided there is an appropriate mechanical environment. Implants can be removed (thus removing the biofilm) if necessary after the fracture has healed.

**References**

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**24 Treatment strategies for non unions**

**Learning objectives**

At the end of this session, participants should be able to:

* List reasons for development non unions
* Diagnose different forms of non union
* Formulate a detailed plan to deal with viable and non viable non unions
* Anticipate challenges and complications

Nonunion, by definition, is the failure of a fractured bone to heal, regardless of healing time. In a more practical sense, it is the failure of bone to heal in the expected time frame for a specific patient and type of injury. Nonunions occur due to a failure of mechanics, biology or both. Nonunions can be classified into two large groups; viable (biologically active, failure of mechanics) and nonviable (biologically inactive).

Viable nonunions have variable amounts of callus but this callus fails to bridge the fracture gap. Viable nonunions occur due to failure of mechanics, i.e. instability and resultant motion at the fracture site due to inappropriate choice of fixation. Depending on the amount of callus present, viable nonunions can be further subdivided into hypertrophic (elephant’s foot), slightly hypertrophic (horse’s foot) or oligotrophic. Although oligotrophic nonunions do not show radiographic signs of callus, they remain biologically active. Oligotrophic nonunions are often a result of loose implants such as cerclage wires in the area of the healing fracture.

Nonviable nonunions can be divided into dystrophic, necrotic, defect and atrophic. In dystrophic nonunions, vascular compromise results in nonviable bone on one or both ends of the fracture. In necrotic nonunions, major bone fragments become devascularised, necrotic and infected, resulting in sequestrum formation. A defect nonunion is a gap at the fracture site that is too large for normal healing processes to overcome. Atrophic nonunions are often the end result of defect nonunions, where the fracture ends are resorbed and yet not restored.

For treatment purposes, nonunions can be classified as those demonstrating callus formation (hypertrophic and moderately hypertrophic) and those with no callus formation (viable oligotrophic and nonviable nonunions). For viable nonunions with callus formation, the problem is mechanical and replacing the fixation with a more rigid type should allow healing to progress. Nonunions with no callus formation have adequate or excessive stability, and require strategies to encourage a biologically active environment.

Loose or broken implants should be removed, along with any nonviable bone or sequestra and devitalized soft tissue. Sclerotic or atrophic bone ends can be foraged prior to rigid internal fixation, ideally with bone plates. The bone ends can be osteotomised and axial compression applied across the new transverse fracture lines in order to improve load sharing between the implants and bone. This will result in bone shortening, which is unlikely to be clinically relevant.

Although strategies to improve biology may not be necessary in viable nonunions, they are often utilised. Aggressively promoting biologic activity is mandatory in nonviable nonunions. A variety of materials are available to encourage bone healing and may have a source of cells, growth factors and/or a scaffold. Options include autogenous bone graft, demineralized bone matrix, bone

marrow and growth factors (for example rhRMP-2 or platelet rich plasma) (Milovancev et al, 2007). Application of omentum as a free non-vascularised graft has also been described as means to improve biology at the site of an avascular non-union in dog models and in clinical cases (McAlinden et al, 2010).

**Key points**

- Nonunions can be classified as viable (hypertrophic, moderately hypertrophic or oligotrophic) or nonviable (dystrophic, necrotic, defect and atrophic)

- Treatment strategies depending on the underlying cause; viable nonunions can be treated by improving mechanical stability whereas nonviable nonunions require aggressive promotion of biologic activity

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Milovancev M, Muir P, Manley PA, et al: Clinical application of recombinant human bone morphogenetic protein-2 in 4 dogs. Vet Surg 2007;36(2);132–140