How to Use Bone Plates in Practice Mini Series

Session Three: Complications- how to avoid and resolve

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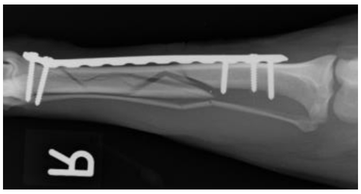

How to Use Bone Plates in Practice
Session 3- Decision Making and Complications

Fracture Treatment

The best way to avoid complications is successful fracture treatment at the first attempt.

Successful fracture treatment begins when the patient is first presented. It is essential not to be pre-occupied by the fracture. When presented with a trauma patient it is vitally important to assess the systemic health of the animal. This may sound obvious but some trauma patients can look remarkably well despite significant hidden pathology. Initially the examination consists of a rapid but thorough examination to assess for life threatening conditions. A more thorough examination follows this. Assess the animal for other traumatic injuries, pneumo-, haemothorax, hernias, splenic/hepatic haemorrhage, head trauma, rib fractures, bladder rupture and ureteral avulsion. For the thorough examination a system approach (e.g. thoracic, abdominal) or regional approach can be use but it is best to follow a set routine that you are comfortable or familiar with to minimise the risk of missing something. Observation and repeat examinations are paramount to assess for hidden pathologies.

A full orthopaedic and neurological examination should be performed without focusing on an obvious fracture. Having said that not all fractures are obvious and signs such as swelling, skin discoloration and pain can help localise relatively stable or incomplete fractures. It is vital to assess the remainder of the musculoskeletal system focusing on the mobility of the patient, assessing for other fractures and assessing joints for sub-luxations or luxations. With severe trauma it is essential to assess tissue viability and neurological function, both of which can be difficult. Tissue viability can be assessed by the warmth of distal extremities or if the tissue bleeds with a needle prick. However when there is shock and peripheral vasoconstriction these tests may be difficult to interpret. Again neurological function can be difficult to assess but mentation, cranial nerve reflexes, gait, posture, proprioception and segmental spinal reflexes can all be used to assess neurological deficits.

Initial stabilisation with analgesics, intravenous fluids, oxygen supplementation and blood products should commence as soon as possible with repeat assessments essential.
Once stable your attention can turn to assessing the fracture. High quality **orthogonal** radiographs are essential. To obtain these general anaesthesia is required and the adjacent joints should be included. Obtaining radiographs of the contralateral limb if comparison is required to help make a diagnosis and for implant templating to guide decision-making. If the patient is not stable for general anaesthesia and an interim diagnosis is required radiographs obtained when conscious or sedated can be obtained however high quality radiographs obtained under GA will almost certainly also be required. Computed tomography can be useful to assess fractures of the skull, spine and pelvis or when the fractures is highly comminuted as 3-D reconstruction can aid decision-making and surgical planning.

Treatment of fractures can be achieved by conservative means, external coaptation, internal fixation or external skeletal fixation. Each fracture needs to be assessed individually. It is essential that you do this and don't search for a picture of a similar fracture and try to copy the repair. Assessing the fracture requires information to be apportioned to the three main categories - **mechanical, biological and clinical factors.** By following this it ensures all relevant information is considered and it allows a Fracture Patient Assessment Score (FPAS) to be created. Each of categories are assigned a score on a scale 1 -10, with 10 being most favourable and 1 being least favourable. In reality scores are given a high (8-10), medium (4-7) and low (1-3) with high indicating a likely better outcome with fewer complications and low indicating a greater risk of a poorer outcome with a more complications. The FPAS can then be used to guide surgical approach, reduction techniques, tissue management, implant selection and postoperative care.

Low FPAS – elderly but boisterous patient with comminuted fracture and considerable soft tissue damage. Slow bone healing anticipated with the implants being subject to all the disruptive forces. The repair must be stiff and strong and last for an extended period.
High FPAS – small young patient with simple fracture. The repair does not have to be as robust.

Mechanical factors

High Risk (1-3)	**Medium Risk (4-7)**	**Low Risk (8-10)**
Giant Breed	Large breed Medium Breed	Small Breed
Multiple limbs affected		Single limb affected
Comminuted fracture	Reducible fragments	Simple fracture
Pre-existing ortho or neuro disease		No pre-existing ortho or neuro disease

Biological Factors

High Risk (1-3)	**Medium Risk (4-7)**	**Low Risk (8-10)**
High energy fracture		**Low energy fracture**
Diaphyseal fracture		**Metaphyseal fracture**
Extensive soft tissue injury		**Limited soft tissue injury**
Extensive approach	**Closed approach**	**Limited approach**
Elderly	**Middle aged**	**Juvenile**
Concurrent disease		**No concurrent disease**
Concurrent injuries		**No concurrent injuries**

Clinical Factors

High Risk (1-3)	Medium Risk (4-7)	Low Risk (8-10)
Poor client compliance		Good client compliance
Poor patient compliance		Good patient compliance
Boisterous, hyper-responsive patient		Calm, stoic patient

A treatment plan should be made before surgery however in your mind there should be plan A, B and C as your assessment of the fracture will frequently change during surgery. The implants you are planning to use can be estimated from templating the radiographs. It is important to anticipate complications to take steps to avoid them. You should be aware of both the mechanics and the biology of the fracture and your planned repair.

There is a balance to be sought between the

Mechanical advantage of reconstruction
Versus
Biological disadvantage of surgical exposure

and

Mechanical disadvantage of not reconstructing
Versus
Biological advantage of minimal surgical exposure

Most fractures repair fail because the surgeon inadequately address's the mechanics of the fracture rather than the biology.

After all fracture surgery **orthogonal** post-operative radiographs should be obtained. Follow up radiographs should also be obtained although in many circumstances especially if the animal is doing well they are not. The radiographs should be assessed for the **Fours A's Of Fracture Repair.**

Alignment
- Assess entire bone and in particular the joint above and below
- Evaluate limb in terms of angular and torsional alignment relative to normal
- Goal is to return and maintain limb in normal alignment

Apposition
- Evaluate realignment of fracture fragments for apposition
- Desired amount of apposition is dependent upon fixation method
- Maintenance of apposition is important during follow up evaluations

Apparatus
- Assess appropriateness of implants chosen and state of implants
- Evaluate each individual implant for evidence of current or impending failure

Activity

- Assess biological activity of bone in response to fixation (i.e. callus formation)
- Evaluate fracture site for evidence of lysis and periosteal new none formation
- Evaluation requires knowledge of patient's age, time since repair and consideration of factors such as infection or other wounds/injuries

Open fractures

An open fracture is one in which fractured bone is exposed to environmental contamination due to disruption of the soft tissue integrity. They present a unique combination of soft tissue and orthopaedic injury. Referral is always advised as better results occur with experience.

Open fractures vary in severity and are classified based on the degree of soft tissue damage.

- Type I
    - Wound smaller than 1 cm
- Type II
    - Wound larger than 1 cm
    - Without extensive soft tissue damage, flaps or avulsions
- Type III
    - Extensive soft tissue damage
    - IIIA - Adequate soft tissue coverage of bone despite extensive soft tissue laceration or flaps
    - IIIB – Extensive soft tissue loss, periosteal stripping and bone exposure with massive contamination
    - IIIc – Associated with arterial injury requiring repair

The aim of treatment is to restore soft tissue coverage to healing bone, tendons, ligaments and neurovascular structures.
Not all open fractures are infected – they are all contaminated. Whether contamination develops into infection depend on a number of factors

- The amount of bacterial contamination
- Time between contamination and treatment
- Patient factors – age, concurrent disease
- Type of wound
    - Crush injuries can lead to major soft tissue injury
    - Devascularisation

Key initial principles

- Assess for vascular and neurological deficits
- Prompt and aggressive debridement of contaminated material and non viable tissue
- Cover with sterile dressing until this can happen
- Vigorous irrigation
- Administration of antibiotics
- Intravenous initially and ASAP
- Bacterial swab of wound before start
        - In humans often don't culture bacteria likely to cause infection
- Early fracture fixation and soft tissue reconstruction

Definitive treatment

Soft tissue closure can be achieved by

- Primary closure
- Second intention healing
- Axial pattern flaps or free skin grafts

Fracture treatment

- External Coaptation not recommended
- Internal or External fixation can be used

- Principle of ‘no metal in contaminated fracture’ challenged
    - Internal fixation regularly used in humans
- However internal implants may require removal
- Severe tissue loss may preclude internal fixation.

Complications of open fracture surgery include superficial infection, deep infection (implant associated or osteomyelitis), delayed union or nonunion, necrosis of soft tissue, wound reconstruction dehiscence and neurological damage

Management of fractures

Fractures can be treated by
- Conservative
- External coaptation
- Internal fixation
- External skeletal fixation

Conservative

There are a number of situations where conservative treatment with strict rest (often a cage) can be considered.
In very young animals the periosteum may remain complete resulting in minimal displacement in which case conservative treatment is entirely appropriate. Healing of the fracture should be assessed radiographically regularly, 5-7 days after the diagnosis. Fracture disease e.g. quadriceps contracture is a possibility so early limb use is necessary. If there is any fragment displacement then reduction and stabilisation is best.
Pelvic fractures can be treated by cage rest however surgery is best if there is disruption of the weight bearing axis and or a decrease in pelvic canal width. Pain is also better controlled with stabilization of the fragments.
Minimally displaced/incomplete fractures can also be treated with strict rest but again regular radiographic evaluation of healing is required.

External Coaptation

External coaptation is a popular means to treat fractures as it is considered easy. It is actually not easy and can be difficult to achieve the best outcome possible. Patient comfort and tolerance is vital to success.
External coaptation is appropriate in several situations
- Young patient with fast healing
    - Very young patients should not be placed in bandages or casts
- Stable minimally displaced or Incomplete fractures
- Ulnar fractures with intact radius

However good internal or external skeletal fixation will almost always results in a better outcome.

The advantages of external coaptation compared to surgery are
- Disruption to fracture site is minimal
- Blood supply is not further compromised
- No implants or surgery so risk of infection is decreased
- No implants that may need removal
- Can be cheaper (but not always)

However the disadvantages are
- Need to immobilise joint above and below fracture
    - Impossible in proximal limb
- Prolonged immobilisation can result in disuse atrophy and fracture disease

- Inadequate reduction
- Inadequate alignment

Assessment of the patient and fracture are the key to success.
Patient assessment
- Young patients heal quickly thereby limiting time in coaptation
    - Very young animals should not be put in coaptation
- Breed is important
    - Antebrachial fractures in toy and small breeds
    - Never use external coaptation (83% risk of malunion/nonunion)
- Patient conformation
    - Difficult in obese animals or chondrodystrophoid breeds
- Soft tissue injury
    - External coaptation less than ideal
- Multiple limb injury
    - Patient temperament

Fracture assessment
- Fracture environment – open v closed
- Type and location of fracture
- Degree of displacement
- Multiple fractures
- Fracture forces present
    - Can counteract bending and rotation
        - Provided joints above and below fracture are immobilised
    - Cannot counteract compression, tension and shear
        - Most fractures are under axial compression

Basic guidelines for external coaptation
Fracture reduction
- Healing is greatly influenced by fracture reduction
- 50% rule
    - 50% contact for healing to be possible
    - Aim for 100%
- Closed reduction very seldom achieves perfect reduction
- Weight bearing after application likely to disrupt reduction

Fracture alignment
- Rotational alignment between proximal and distal joints
- Imperative to limb function
- Rotational or angular limb deformities
    - Functional gait abnormality
    - Lameness due to secondary osteoarthritis

Standing position
- Joint stiffness common after external coaptation
- Prolonged immobilisation
    - Adhesions between muscle, tendons and bone
- Neutral standing position
- Limb should be used after application
- Joint mobilisation as early as possible

Joints proximal and distal
- To counteract bending and rotation the joint proximal and distal must be immobilised
- Distal to elbow and stifle

Temporary immobilisation
- Prior to definitive surgery
- Useful for open fracture management
- Travelling
- Most dogs don’t need if cage rested with sedatives and analgesia
    - Poorly applied immobilisation causes more problems

There are many types of external coaptation - bandages, casts, splints, slings etc. and the precise nature and application of each can be found in an orthopaedic textbook. The Robert Jones dressing and synthetic casts are the most applicable. All bandages etc. must be kept clean and dry with close monitoring for the bandage slipping, smelling and development of sores. Dogs generally do not chew at bandages/casts that are well placed causing no irritation.
External coaptation has a role in veterinary orthopaedics where there are financial constraints, minimally displaced or incomplete fractures, adjacent bones intact, metacarpal, metatarsal, digit fractures (one or two affected especially non weight bearing digits) and as adjunct stabilisation (malleolar fractures). However external co-aptation should not be used to try and protect an inadequate fracture repair.

Surgical stabilisation of fractures gives a more predictable outcome, earlier return to function and minimise delayed, non- and mal- unions. Bone plates are preferable to external skeletal fixation as they have been shown to have a lower complication rate and improved outcome. In addition bone plates have a better owner satisfaction.

Complications of Internal Fixation

Complications

- Wound dehiscence
- Seroma
- Superficial infection
- Deep infection
    - Implant associated or Osteomyelitis
- Implant failure
- Delayed, non- and mal- union
- Necrosis of soft tissue
- Neurological damage

Wound dehiscence is a rare complication if good closure is achieved initially. It is most often seen with self-trauma of the wound or with a surgical site infection. Closure of the wound defect can be difficult especially in the distal limb and exposure of the implants increases the difficulty. Reconstructing the wound often fails especially if implants are exposed. Often the wound needs to be treated as an open wound especially if further closure fails. The wound will likely heal by second intention healing but if not may require implant removal for ultimate closure.
Seroma is normally the result of poor closure and/or dehiscence of the deep suture layers. Don't aspirate as there is the risk of introducing bacteria. Normally these will resolve over time. If the seroma is large and causing clinical signs then a drain can be placed which requires a surgical prep.

Superficial surgical site infection

- Prophylactic use of antibiotics controversial
- Treat superficial infections rapidly
- Consider inflammation v infection
- Swabs of superficial discharge not particularly useful
    - Culture contaminants
- Deep aspirates better
    - Care not to introduce bacteria
- 7-14 days antibiotics
    - Clinical audit of SSIs
    - Choice of antibiotic based on Culture/Sens or Audit

Deep Surgical Site infection

- Implant associated infection
- Recurrent surgical site infection

    - Discharging sinus
    - Variable pain
    - Variable lameness
- Responds to antibiotics
- No radiographic evidence of osteomyelitis
- Normally requires implant removal to resolve
    - Bacteria live in biofilm

Osteomyelitis

- Inflammation of bone cortex and marrow
- Introduction of bacteria at orthopaedic surgery
- Normal bone is relatively resistant to infection
- Requires
    - Sufficient numbers of pathogenic bacteria
    - Avascular cortical bone
    - A favourable environment for bacterial colonisation + multiplication
        - metal implants, haematomas, necrotic tissue

Acute osteomyelitis

- Within 2-3 weeks of surgery
- Heat, pain, swelling, disuse
- Occasionally systemic illness

Chronic osteomyelitis

- Within several months
- Less obvious, systemic illness uncommon
- Presence of infected, avascular cortical bone
    - Sequestrum

Osteomyelitis is rare despite high incidence of contamination

- Factors that increase likelihood
    - Excessive trauma to soft tissues
    - Periosteal stripping- devascularisation
    - Fracture instability
    - Altered local defences
        - Malignancy, diabetes

The diagnosis of osteomyelitis is based on the history, clinical signs and radiographs. Radiographs reveal bone lysis, periosteal new bone, cortical thinning, possibly the presence of an involucrum (sclerotic bone surrounding sequestrum) or a sequestrum (cortical bone surrounded by radiolucency) and delayed union or non-union of the fracture. The Diagnosis is based on bacteriology with the majority being mono-microbial although polymicrobial (gram positive + gram negative or aerobic and anaerobic) infections being possible. Tissue samples for culture are best, as swabs of any discharge may not isolate the causative organism. Sampling at the time of open debridement is best and this could be affected bone, adjacent soft tissues or removed implants.

Treatment

- Surgical debridement
    - Removal of sequestrum, necrotic soft tissue
    - Copious lavage
- Allow drainage
- Obliterate dead space
- Provide absolute stability at fracture
    - Fixation often requires revision
    - Bone plates offer most rigid fixation
    - Often will require subsequent removal
- Antibiotics
- Prolonged course
- 4-6 weeks minimum

- May require 3-4 months
- Acute cases
    - Obtain bacteriology samples and start antibiotics ASAP
    - Cephalexin, amoxicillin/clavulanate
    - +/- Metronidazole for anaerobes
    - Modify with bacterial culture/sensitivity results
- In chronic cases start after have collected samples.

Preventing Infection
- Good theatre practice
- Good surgical technique
- Perioperative antibiotics
    - Present before initial surgery
    - IV 30-60 minutes before incision
    - Continued for up to 24 hours
    - Post-operative antibiotics
        - Based on surgeon, animal, fracture factors
        - Some evidence decreases infection rates

Implant failure

The implants used to stabilise a fracture restore the bone's structure and function temporarily. It is bone healing that restores it permanently. As a fracture heals the load taken by the implants decreases over time and the load taken by the bone increases. If the bone fails to heal then implants undergo cyclic fatigue and may fail. All metal work will fatigue and it is a race between bone healing and implant failure

Types of implant failure
- Mechanical failure
    - Metallurgic imperfections
    - Manufacturing faults
- Acute overload failure
- Fatigue failure
- Corrosive degradation

Fatigue failure is the most important mode of failure and is caused by repetitive cyclic loads that in isolation would not cause failure. It normally occurs some weeks after apparently successful repair. There is progressive microscopic damage to the metal's structure and micro- cracks form. These propagate until the crack reaches a length beyond which remaining material cannot withstand the stress of loading. The number of stress cycles a metal implant can withstand is inversely proportional to magnitude of stress (i.e. as stress increases the number of cycles the implant can withstand decreases). The concept of stress concentration is important in fracture repairs. In a DCP plate the hole is a 'stress riser' (i.e. there is a force being applied to a smaller area due to the hole, remember stress = force/area). The stress concentration is greater if the fracture is unstable or poorly reduced and the plate has to withstand all the force. This can result in fatigue failure of the implant. Load sharing of the bone (i.e. reconstruction with compression) decreases stress concentration. If this cannot be achieved then the fixation method must take stress concentration into effect (i.e. a stiffer and stronger construct)

Delayed, non- and malunion

Bone healing is naturally vigorous and we as surgeons have mechanical and biological strategies to enhance this healing.
- Mechanical
    - Realign fracture fragments
    - Attenuate motion at fracture site
- Biologic
    - Growth factors and cells (bone graft)
    - Preserve soft tissue viability and vasculature

Inadequate mechanical or biological environment leads to retarded healing (delayed union), unsuccessful healing (nonunion) or improper healing (malunion).

Treatment is aimed at finding the cause and correcting. With inadequate stabilisation (mechanics) treatment is either the removal of loose and or infected implants, complete revision of fixation or the use additional fixation.
With inadequate growth factors/cells (biology) treatment is aimed at preserving the soft tissue and vasculature and bone grafts.

Delayed union

- Prolonged time to heal
- Will eventually heal without specific intervention
- How do we know it will heal and not become a non-union
  - Assess fracture stability
  - Assess fracture biology
    - Evidence of healing- callus
  - Assess for infection
    - Causes implant loosening
    - Reduced O_2 tension + persistent inflammation

Treatment of delayed union

- Give time
- Bone graft
- Limited local debridement
- Revise fracture fixation
- Easier to treat biologically active, non displaced delayed union than chronic, displaced, non viable non union

Non-union

- Radiographic feature is a fracture gap persisting for longer than expected for normal or delayed healing
- Viable nonunion
  - Hypertrophic, oligotrophic
- Nonviable nonunion
    - Dystrophic, necrotic, defect and atrophic

- Treatment
  - Decide on cause and correct
  - Viable non unions
    - Inappropriate mechanical environment
    - Biologically active so placement of graft not absolutely essential
  - Non viable non unions
    - Inadequate biological environment
    - Not all have poor mechanical environment
      - Commonly do

  - Correct underlying cause
  - Inadequate stabilisation
    - Remove loose implants
    - Revise fixation
    - Additional fixation
  - Inadequate growth factors/cells
    - Preserve soft tissue + vasculature
    - Bone graft
    - Distraction osteogenesis
  - Debride necrotic tissue/fibrous callus
  - Infection
  - Key to treatment of orthopaedic infections is ***Stability***

- Fractures will heal in presence of infection if
    - Adequate stability is provided
    - Infection is suppressed by antibiotics

Malunion
With a malunion healing has occurred but there has been a failure to reestablish the form and function of bone

- Functional Malunion
    - No treatment required
- Non-functional Malunion
    - Osteotomy + revise

Necrosis of Soft Tissue can occur with poor surgical technique particularly if wound closure is tight creating a biological tourniquet or excessive trauma occurs to the vascular supply. It can also be the sequelae of bandage complications.
Neurological damage can occur either secondary to the initial trauma or the surgical approach. Excessive retraction of nerves should be avoided and trauma to nerves is more likely with poor anatomy knowledge. Neurological damage is normally a neuropraxia so recovery can be expected within days to weeks. Rarely it can be permanent if the trauma is severe.

Bone Grafting

Bone grafting involves the transplantation or implantation of bone or bone substitute to enhance bone healing and can be used in many situations

- Complex fractures
- Fractures with poor healing potential
- Filling of bone defects
- Arthrodesis
- Intervertebral fusion
- Treatment of delayed or non-unions

Bone grafts can have one or more of the following properties depending on the type of graft

- Osteoconduction
    - Scaffold allowing healing tissue to grow across
- Osteoinduction
    - Stimulation of differentiation of mesenchymal cells to osteoblasts
- Osteogenesis
    - Formation of new bone by graft- must contain osteoblasts
- Osteopromotion
    - Enhancement of bone healing without osteo- inductive or conductive
- Osteointegration
    - Process by which graft material is integrated into host bone

Types of Bone Grafts

- Autografts
    - Cancellous
    - Cortical-cancellous
    - Cortical (vascularised, non vascularised)
- Allografts
    - Cancellous bone chips
    - Cortical grafts
    - Demineralised bone matrix
- Growth Factors
    - Bone morphogenic Proteins
- Synthetic
    - Hydroxyapatite

Autogenous Cancellous Grafts are considered the gold standard as they are osteogenetic, osteoconductive and osteoinductive. They can be harvested from the following sites

- Proximal lateral humerus
    - Base of greater tubercle
- Ilial Wing
    - Dorsal or lateral
- Proximal lateral femur
- Distal femoral condyle
- Medial proximal tibia

A surgical approach is made to the boney protuberance and a hole or holes drilled and volkmann curette used to scoop out graft.

The disadvantages of obtaining an autogenous cancellous graft are it normally involves a second surgical site which increases surgical time, cost and morbidity, there can be pain from the harvest site but although this is commonly recognised in humans it would appear to be less significant in dogs and cats, there is a potential risk of fracture and this risk can be minimised by creating as small a hole as possible and not levering with the curette, finally the graft yield can be variable in both quantity and quality.