Fracture treatment

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Fracture treatment planning and decision making

Karen L Perry BVM&S CertSAS DipECVS FHEA MRCVS

Assistant Professor in Small Animal Orthopedics

Veterinary Medical Center

Michigan State University

736 Wilson Road

East Lansing

MI 48824-1314

Samantha Woods BSc(Hons) MA VetMB CertSAS DipECVS MRCVS

Lecturer, Small Animal Surgery

University of Edinburgh,

The Royal (Dick) School of Veterinary Studies and The Roslin Institute

Easter Bush Campus

Midlothian

EH25 9RG

Abstract

Numerous options are available for fracture stabilisation and every fracture is unique. In order to achieve optimal results following fracture repair, detailed preoperative planning is essential, allowing a tailored treatment plan to be established for each individual. Failure to plan both the surgical procedure and postoperative care adequately can be anticipated to lead to higher complication rates. This article, as the first in the series, gives an overview of different possible approaches to fracture stabilisation, including the more traditional open reduction and internal fixation as well as more biological approaches. Many factors influence the approach chosen for a given patient and these are discussed here. Once a decision is made regarding the approach to be used, a specific stabilisation method must be chosen and guidance is given regarding the broad categories that may be suitable for specific situations. Following this, planning of the surgical repair must take place and several methods are outlined ranging from use of the direct overlay method to digital templating. Subsequent articles in the series will give more specific detail regarding specific types and locations of fracture.

Fracture Treatment – Failing to Plan is Planning to Fail

Introduction

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 detailed planning of the entire surgical procedure and provision of appropriate postoperative care. Failure to plan and anticipate the problems associated with each individual fracture repair will result in prolonged surgery and anesthesia times, 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 (Houlton and Dunning 2005).

Approaches to Surgical Stabilisation of Fractures

When considering surgical stabilisation of fractures two different approaches are recognised. The traditional approach of open reduction and internal fixation (ORIF) was developed and advocated by the AO (Arbeitsgemeinschaft für Osteosynthesefragen) group in the 1950s and 1960s in an effort to reduce the incidence of fracture disease. Fracture disease is a combination of complications including muscle atrophy, joint stiffness and osteopenia that occurred commonly prior to this time when limb immobilisation by external coaptation or bed-confinement with traction were used to treat fractures. The AO principles of ORIF (Perren 1991, Mast et al 1989, Gautier et al 1992) are:

- Anatomical reduction of fracture fragments, especially in articular fractures
- Stable fixation, suitable to the biomechanical and clinical situation
- Preservation of the blood supply to the bone fragments and surrounding soft tissues through atraumatic reduction and surgical technique
- Early, active pain-free mobilisation of muscles and joints adjacent to the fracture to prevent development of fracture disease.

There are several advantages to this approach. Open reduction and internal fixation following these principles results in an anatomically reconstructed and rigidly stabilised column of bone which can load-share with the implants chosen. This reduces stress on the implants and protects them from fatigue failure. Rigid immobilisation also reduces pain associated with ongoing fracture instability and allows full limb use early in the postoperative period. Anatomic reduction and rigid fixation also provide the ideal environment for primary bone healing, avoiding exuberant callus formation that may interfere with adjacent tendons, muscles and joints (**Figure 1**).

However, there are also disadvantages to the traditional ORIF approach. Complete reconstruction of comminuted fractures, as is required for this method, is technically demanding. This practice requires a large open approach necessitating disruption of the surrounding soft tissue envelope and often protracted operating times; factors which increase the risk of infection. If reduction is not precise, forces become concentrated at the small fracture gaps resulting in high strain environments and high focal stresses on implants which in turn may lead to impaired bone healing and fatigue failure of implants.

While the traditional ORIF approach remains very useful for simple fractures and some mildly comminuted fractures, more complex fractures may be better managed by a different strategy. The biological approach to fracture repair has differing principles:

- Alignment of the two main fracture fragments to avoid limb length / angular / torsional deformity
- Provision of relative stability rather than absolute rigidity leading to promotion of secondary bone healing by callus formation
- Minimal (or preferably no) disruption of the intermediate fracture fragments in order to preserve the fracture callus and soft tissue attachments, expediting and facilitating healing.

When using this approach it must be remembered that the bony column has not been reconstructed and therefore cannot load-share with the implants. This leads to greater stresses on the fixation system which must be accommodated through implant choice in order to avoid fatigue failure. All fracture stabilisation systems can be used with this approach including plates and screws, interlocking nails (ILNs) or external skeletal fixation (ESF). Minimally invasive techniques such as minimally invasive plate osteosynthesis (MIPO) or minimally invasive nail osteosynthesis (MINO) may be used and (certainly) adhere to the principles noted above (**Figure 2**). Alternatively, implants can be placed using an 'open but do not touch' approach where a traditional open approach is made but manipulation of the fracture fragments is avoided unless absolutely necessary.

Radiographic Examination

Orthogonal views of the affected bone including the proximal and distal joints are essential for accurate diagnosis, fracture assessment and selection of the best procedures for reduction and immobilisation. Radiographs of the contralateral limb should also be taken, particularly when evaluating articular and complex fractures of curved bones. Computed Tomography (CT) may provide details essential to the diagnosis in select cases.

Because movement of fracture fragments inevitably results in pain, radiographs usually require sedation or short-acting general anesthesia. If this presents a problem due to concomitant morbidity, it may be necessary to delay radiography. In this situation it is often helpful to obtain the one view that can be taken without anesthesia to confirm the location and severity of the fracture. This then allows the formation of a basic treatment plan. Bear in mind that the second view should be taken before attempting reduction and stabilisation (DeCamp et al 2016).

Radiographs should be carefully examined to identify any evidence of pre-existing pathology which could indicate a pathologic fracture. The presence of neoplastic, other systemic disease or, less commonly, dietary deficiencies may alter the treatment plan. Any non-displaced fissures (**Figure 3**) and the distance of fissures or fragments from joints should be noted as well as the width of the bone in various places and differing planes. These measurements will be critical in choosing the method of fracture stabilisation as well as anticipating potential complications.

Factors to Consider when Deciding on Fixation Method

There are many factors that influence the fixation method chosen for a given fracture and all of these should be considered carefully prior to making a definitive treatment plan. Each patient must be considered as an individual with an appropriately tailored strategy. For ease of discussion, these have been divided into mechanical, patient, biological and surgeon factors here but there is considerable overlap between these categories.

Mechanical Factors

When assessing a fracture the surgeon must ascertain whether full reconstruction of the bone column is possible. Restoration of the anatomy permits sharing of the weight-bearing load with the implant and will protect the implant from fatigue and early failure. An unreconstructed fracture however relies entirely on the implant to sustain axial loading. Implants bearing the majority of the load in an unfavourable mechanical environment must be larger, stronger and more stable for extended periods of time (Houlton and Dunning 2005).

If the fracture can be anatomically reconstructed, the advantages and disadvantages of this approach should be considered. Generally, articular fractures, simple fractures and fractures with two or three large segments are appropriate for anatomical reconstruction (Houlton and Dunning 2005). Articular fractures specifically must be anatomically reconstructed if a functional result is to be achieved. While anatomical reconstruction provides mechanical advantages for the bone-fixation construct, these advantages must be weighed against the biological cost of this procedure. An open approach and anatomical reconstruction will inevitably disrupt the soft tissues at the fracture site and as the fracture complexity increases so does the associated biological cost. For severely comminuted fractures, major segment alignment via a more biological approach may be selected with the aim being to ensure appropriate alignment of the joints proximal and distal to the fracture but without anatomical reconstruction of the cloud of fragments.

When considering options for fracture stabilisation, the forces that will act to disrupt the fracture fragments once they are reduced should be considered; the stabilisation method chosen must be able to neutralise these forces. The diaphyses of long bones are subjected to three extrinsic forces during locomotion: bending, rotation/torsion and axial compression. Simple transverse fractures will be resistant to axial compressive forces when reduced, but remain unstable to bending and rotational forces. Oblique fractures are unstable to bending, torsion and axial compression with axial compression producing shear forces at the oblique fracture surfaces. Comminuted fractures are unstable to all three forces.

Patient Factors

Patient considerations such as age, weight, presence of concurrent injuries, overall general health, expected activity level, intended use of the animal and ability of the owner to perform postoperative care should all be carefully considered when choosing the method of fracture repair. The bone affected will influence the stabilisation options available and hence the planning of the repair. For example, safe corridors for external fixator pin placement become limited in the proximal limb. Additionally, due to the proximity of the body wall it becomes more difficult to create a sufficiently strong ESF construct for femoral and humeral fractures necessitating additional strategies such as augmentation with a 'tied-in' intramedullary pin to improve construct stability. This may make internal fixation options more desirable for proximal limb fractures. Another example is that intramedullary devices should never be used in the radius as placement is impossible without damaging a joint. The use of interlocking nails and I-M pins is therefore generally limited to humeral, femoral and tibial fractures, except in large breed dogs where placement of an intramedullary device in the ulna can be used to stabilise antebrachial fractures if necessary.

Patient demeanour may play a role in decision-making. For example, there is generally more postoperative care involved with use of an ESF than with internal fixation. In nervous or aggressive patients, postoperative management may be easier following use of internal fixation options. While ESF is tolerated very well in most cases, there may be more concern regarding direct interference with the frame or knocking/catching the frame on surrounding objects in particularly boisterous patients prompting preferential use of internal stabilisation systems (Moores 2008b).

An additional patient factor to consider is animals with polytrauma or multiple orthopaedic injuries. These patients may be forced to take more weight prematurely on an injured limb, hence placing greater demands on their implants (Houlton and Dunning 2005).

Biological Factors

Young animals with an active periosteum and fractures of the metaphyseal region with an abundance of cancellous bone tend to heal rapidly whereas, comminuted high-energy fractures may have impaired vascularity leading to longer healing times. Geriatric or debilitated animals, or animals that have sustained substantial soft tissue injury, will also experience prolonged healing times. Where protracted healing times are anticipated, stable implants will be required for extended periods of time.

Surgeon Factors to Consider

Most fractures may be managed appropriately using more than one stabilisation method and surgeon preference often plays a role in decision-making. Factors which may influence surgeon preference include expertise, previous experience, available equipment and financial constraints of the owner.

Once all these factors have been considered and the mechanical and biological environment of the fracture is known, a decision regarding the appropriate type of fixation can be made.

Planning Fracture Fixation

Following assessment, the decision may be reached that surgical stabilisation is not required. Some patients may be managed successfully with external coaptation. Appropriately applied external coaptation, including the joint above and below the fracture, will limit bending forces and provide some resistance to rotational forces. Where it is not possible to immobilise the joints above and below the fracture, such as for fractures of the humerus and femur, external coaptation is not an appropriate method. External coaptation also provides very limited resistance to axial compression and should only be used in fractures inherently stable to this force. This limits the use of external coaptation to transverse fractures and fractures involving only one bone of a paired bone system. External coaptation is also only appropriate in cases where closed reduction techniques facilitate at least a 50% overlap of the fracture ends (Moores 2008a).

If the decision is made that surgical stabilisation is required, only three methods are available which satisfactorily neutralise all three extrinsic forces acting on fractures; plates and screws, ILNs and ESF. While intramedullary (IM) pins are very effective at neutralising bending forces, they provide no resistance to rotational or compressive forces. Given that all diaphyseal fractures are unstable to at least one of these two forces, the use of IM pins in isolation cannot be recommended. They are often advantageous when used in combination with other techniques such as with plates (producing the 'plate-rod construct') or with ESF (as a 'tie-in').

The ideal fracture fixation method is determined by the perceived balance between quality of fracture reduction, degree of rigidity of fixation and amount of soft tissue damage caused in achieving these for any given fracture and patient age or type (Miller 2006). While certain methods may be inappropriate there is likely to be more than one choice of fixation for every fracture. For simple transverse fractures, compression plating is often performed although ILN, non-compression plating, ESF or combination techniques would also be applicable. For oblique or spiral diaphyseal fractures, interfragmentary compression with lag screws followed by neutralisation plating would be appropriate but cerclage wire could also be used in place of the lag screws or an ILN instead of the plate. For severely comminuted fractures, serious consideration must be given to the value of reconstruction versus the risk for further iatrogenic trauma. Under these circumstances, the ideal fixation method depends upon the morphology of the fracture and must be tailored to the individual case. For severely comminuted diaphyseal fractures an ILN is a good choice, however, for reconstructible fractures interfragmentary compression with lag screws or cerclage wire followed by neutralisation plating may be possible. Partial reconstruction with lag screws or cerclage wire followed by use of a bridging plate or ESF may be performed or minimal or no reconstruction followed by bridging fixation using a plate, plate-rod, ESF with IM pin 'tie-in' or ESF alone could be used.

Planning

Once the type of fracture fixation and method of reduction have been chosen, several planning techniques may be used. The first and most simple method is the direct overlay method, in which radiographic tracings of the fracture fragments are used to plan the reduction. Each fracture fragment is individually traced on a separate sheet of tracing paper. The 'fracture' is then reduced by laying each of the fracture tracings over a tracing of a straight line along the bone's physiological axes to make a final composite drawing (Houlton and Dunning 2005). Anatomically reconstructable diaphyseal fractures of the long bones are generally planned using this method. The appropriate size of implants may then be selected and tested on the reconstructed composite using either acetate templates or non-sterile implants.

The second planning method requires a radiograph of the patient's intact contralateral bone. An outline of the intact contralateral bone is created by inverting the craniocaudal radiograph and tracing a template on to tracing paper. The tracing of the normal bone is placed over the radiograph of the fracture and the intact shaft is aligned to allow the most proximal fracture line to be traced. The intact edge of the distal fragment is then also aligned with the tracing and the fracture line is traced in the reduced position. These steps are repeated until all the fracture lines have been outlined and the fracture reconstructed (Houlton and Dunning 2005). The appropriately sized implants may then be selected using either acetate templates or non-sterile implants. This fracture planning method is of particular use in articular fractures.

The third planning method is less frequently used, but involves a bone specimen of a similar sized animal. This may become more popular in the future given the increasing availability of cost-effective three-dimensional printing. Using the radiographs, the fracture lines are drawn directly on to the bone in the approximate location of the clinical case (Houlton and Dunning 2005). The appropriately sized implants may then be selected, contoured, and tested on the specimen. This technique has the advantage that the implant can be precountered prior to surgery, thus saving valuable intraoperative time.

With the increasing availability of digital radiography, these first three methods may be less commonly used with many surgeons electing to move to digital templating. OrthoView® is one of the better known companies offering veterinary orthopaedic digital planning (OrthoView Vet). A scaling mechanism within the software allows scaling of the digital radiographs as long as a calibration object is present. It is possible to simulate fracture reduction using the software and then a comprehensive selection of digital prosthesis templates are available which can be applied (**Figure 4**). Orthoplan Elite produced by Sound® is another software option for surgical planning.

Once the final plan has been made, it is important to check the implant and instrument inventory prior to surgery. In addition, a thorough review of the relevant anatomy and surgical approach will reduce surgical time and minimise intraoperative iatrogenic damage.

Although it is very important to plan the entire surgical procedure, it is equally important to remain aware that plans do sometimes need to be changed intraoperatively. It is worthwhile to have considered what plans B and C will be in the event that plan A does not proceed well. The difference between plan A and plan B is generally time-dependent. The well-prepared, self-aware surgeon is able to identify when they have ceased to make progress and it is then that plan B may come into play.

Conclusion

Numerous options are available for fracture stabilisation and every fracture is unique. Preoperative planning is essential and allows a tailored treatment plan to be established for each individual which will minimise the risk of complications in the immediate and longer-term. The plan should be made based on a sound understanding of the mechanical and biological requirements for fracture healing. Remember that the best chance of a successful outcome for any fracture patient is with an appropriately planned and executed first surgery (Moores 2008b). Revision surgeries are generally associated with greater risk of complications, reduced chance of a successful outcome and significantly more expense than an appropriately performed initial surgery.

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Figure 1 -Example of ORIF with anatomic reconstruction approach

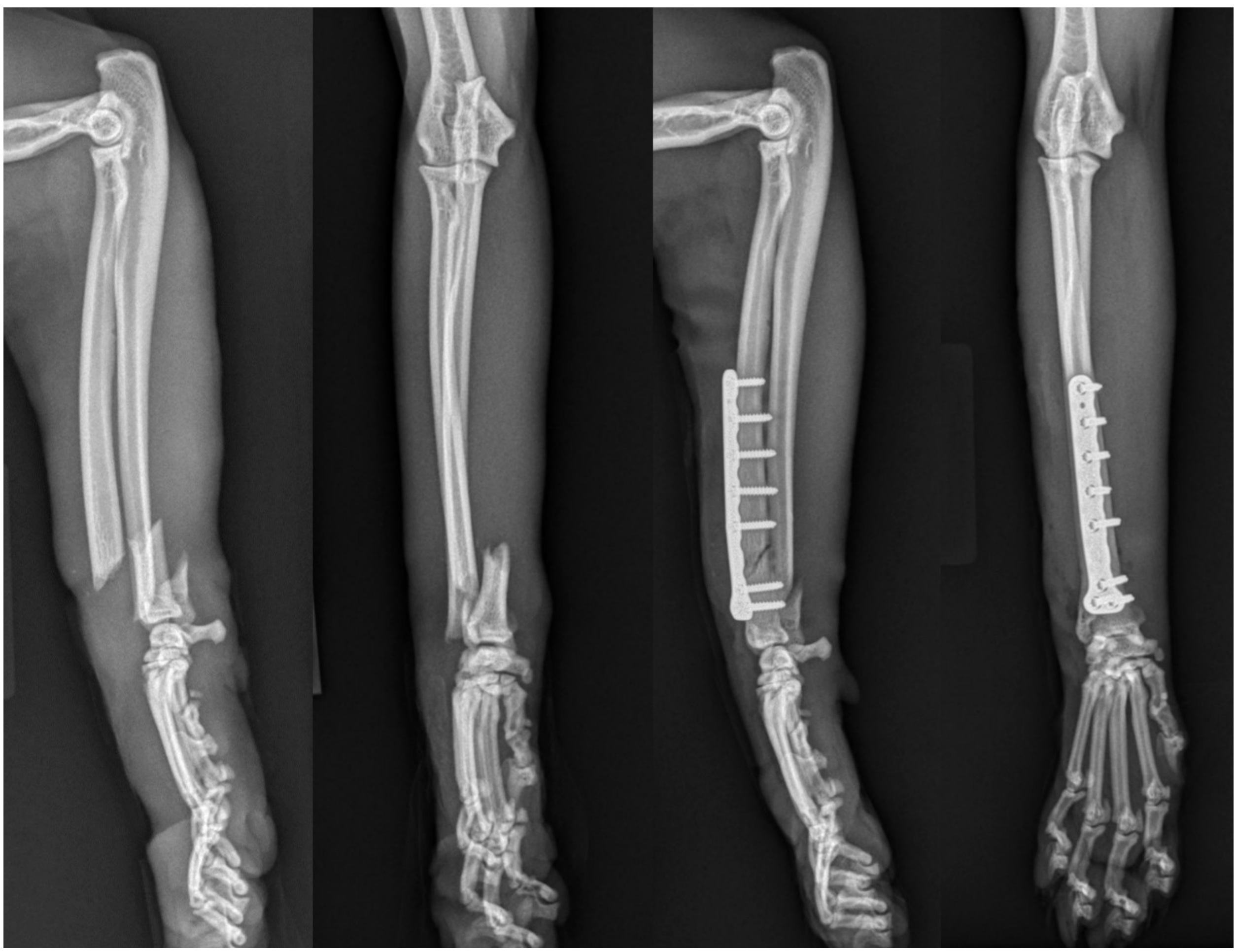

Figure 2 - Example of a biologic approach with MIPO

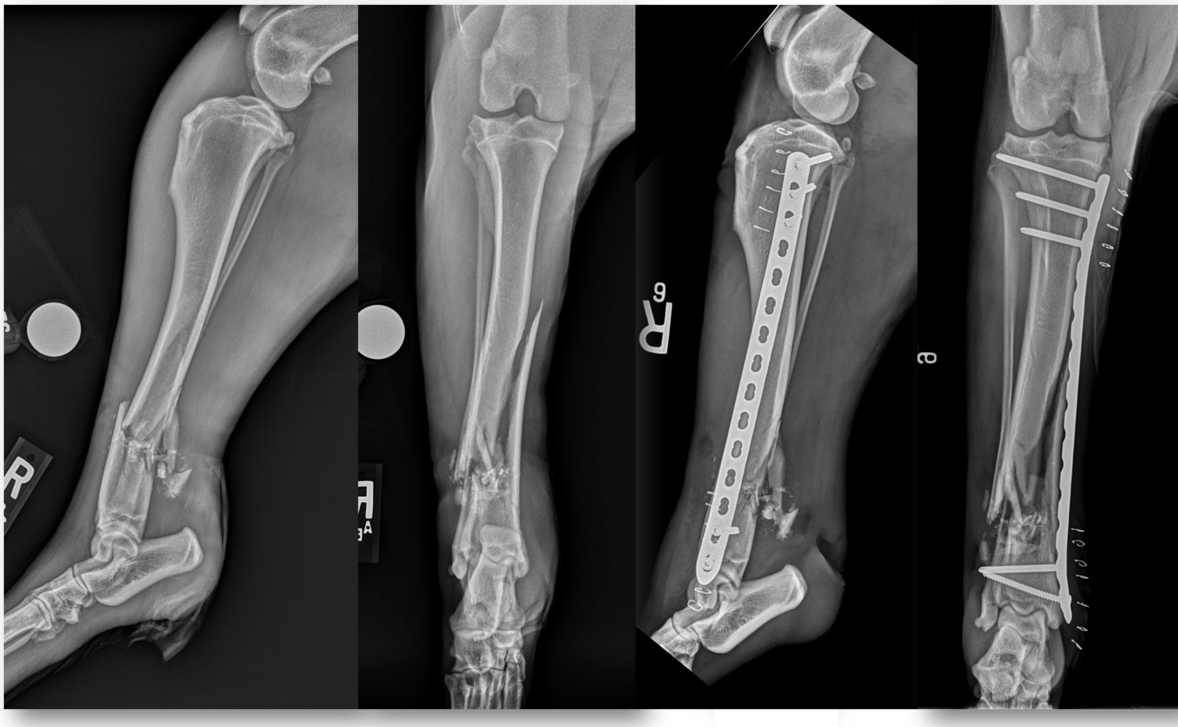

Figure 3 - Example of a non-displaced fissure running distally on radiographs and subsequent repair with lag screws and ILN

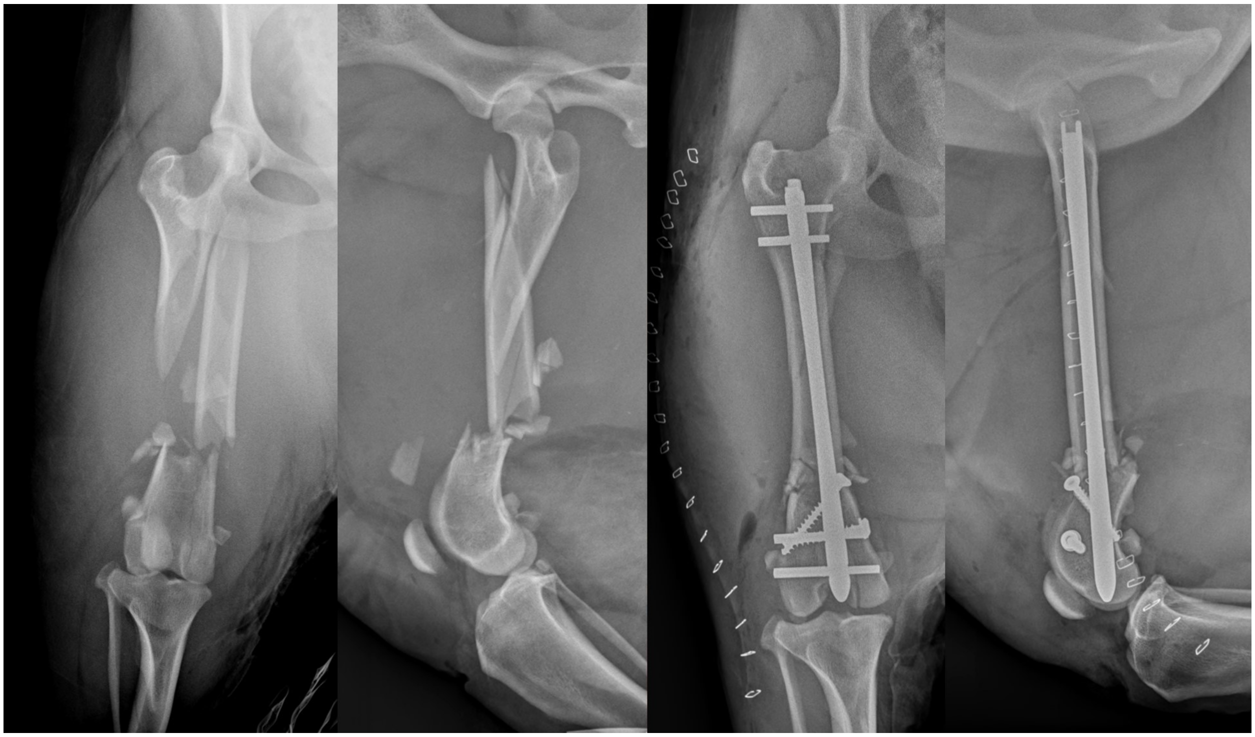

Figure 4a -Fracture Planning on OrthoView - ILN in fractured bone with fracture reduced

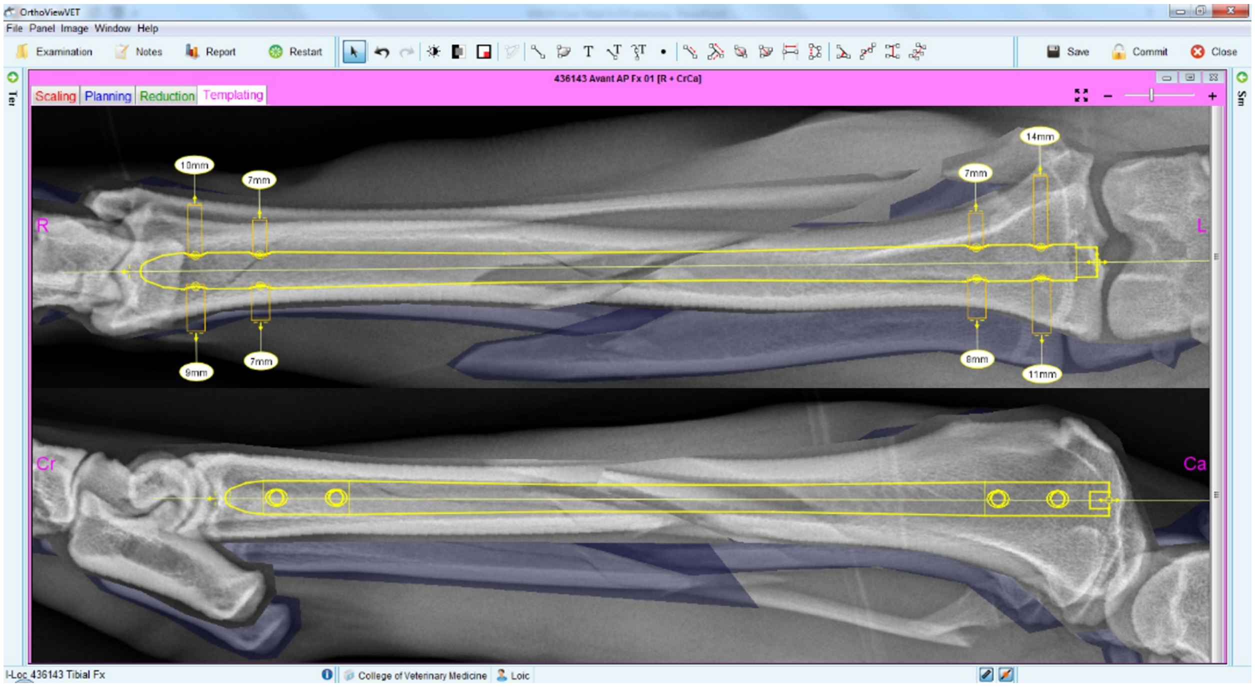

Figure 4b -Fracture Planning on OrthoView - ILN in intact bone