**Clinical approach to the fracture patient**

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**Bone healing**

For bone healing to occur biological and mechanical conditions must be satisfied. Biologically, the blood supply to the bone must be preserved; mechanically, disruptive forces must be neutralised to give a low strain environment.

When a long bone is fractured the intramedullary blood supply is almost always disrupted for a period of time. The healing fracture has to rely in the short to medium term on the **extraosseous blood supply.** This blood supply, from surrounding muscle attachments to the fractured bone and the soft tissue envelope, is critical. There are three aspects to consider with regard to the quality of the soft tissue envelope and therefore the quality of the extraosseous blood supply:

* **Soft tissue envelope *prior* to the fracture.** This depends on the location of the fracture. The more muscle around a bone the better the soft tissue envelope. The best envelope is around the femur or pelvis. The worst envelope is around the distal radius, distal tibia and metacarpal or metatarsal bones.

* **Soft tissue envelope *after* the fracture.**This depends on how much damage has occurred to the soft tissue envelope at the time of the fracture. High energy comminuted fractures will have quite major damage to the surrounding muscles which will compromise the blood supply. Low energy fractures (e.g. spiral or simple transverse fractures) will have limited damage to the surrounding envelope.
* **Soft tissue envelope *after the fracture repair.*** This depends on whether the fracture repair is performed closed or open and, if it is done open, how much soft tissue damage you as a surgeon cause. For example, closed placement of a plate through a minimally invasive approach (MIPO) will cause minimal additional damageto the soft tissue envelope. The other extreme to this is a full open approach where the surgeon does not respect Halsted’s principles and causes considerable iatrogenic damage to the soft tissues.

Mechanical stability at the fracture site can be considered in terms of **strain**. This is a mechanical principle that describes the amount of movement, or deformation, at a fracture gap with respect to the size of the original gap. For instance, if a gap of 1mm is present and the bone ends move apart by 1mm, this represents 1/1 which is 100% strain; if the gap is 1mm and the bone ends move apart by 0.1mm this represents 0.1/1 which is 10% strain.

Pluripotent stem cells at the fracture site respond to the degree of local deformation (i.e. strain) at the fracture gap, which determines their differentiation and the type of tissue they will produce. This is the **interfragmentary strain theory**. Different tissues tolerate different strain boundaries:

* Bone <2%
* Fibrous tissue & cartilage < 10%
* Granulation tissue up to 100%

If the stability of a fracture repair is poor (interfragmentary strain >10 %) then granulation tissue is the only tissue that can readily survive. This granulation tissue can provide a bridge between the fracture fragments which starts to decrease the strain environment. However, in some cases, the weak link formed by granulation tissue is insufficiently strong to decrease strain, and healing cannot progress resulting in a **non-union.** In addition, implants are subject to long term repetitive bending forces; the implants undergo cyclic fatigue and implant failure is usually seen.

If biological and mechanical conditions are satisfied, fracture healing can progress in one of two ways:

*(i) Primary bone healing*

This occurs under conditions of **absolute stability** - strain at the fracture site must be less than 2%. This is generally achieved by accurate reduction and compression of fracture lines. Bone formation in the fracture is direct – the formation of intermediate stages of fibrous callus and cartilaginous tissue are not seen. This form of fracture healing is relatively uncommon compared to secondary healing. Primary bone healing is not necessarily better than secondary healing, rather it is a consequence of how a fracture is treated. Primary healing is seen most commonly following accurate reduction and compression of simple fractures.

*(ii) Secondary bone healing*

When stability at the fracture site is controlled but not absolute, a clinical situation known as **relative stability**, healing will progress by secondary bone healing. This is characterised by the formation of a fibrous callus, which then undergoes progressive chondroid metaplasia, mineralization and ossification to produce a bony callus. This is then slowly remodelled back to normal cortical bone. As healing tissue forms, the strain at the fracture site is decreased which allows progressively stiffer tissues to form. Secondary healing is seen most commonly when bridging fixation is applied to comminuted fractures with no attempt to reduce intermediate bone fragments.

Depending on the fracture configuration and how the fracture is managed, different biological and mechanical microenvironments can exist at different points throughout some fractures. The fracture heals by a combination of primary and secondary bone healing.

**Influence of surgery on bone healing**

Some non-displaced simple fractures can heal with conservative treatment, especially in younger animals. However, in most cases more predictable and optimal outcomes will be achieved following surgery.

Surgery can be used to achieve fragment reduction and to apply fixation to control strain at the fracture site. Stable fixation allows re-establishment of vascularity and also allows early limb use, which minimises fracture disease.

Surgery can also be detrimental if not performed well – vascularity can be disrupted and infection and other complications can be introduced. The key to fracture surgery is understanding the basic aims and principles, and then planning and performing surgery carefully.

**Principles of Fracture Surgery**

For all fractures, the basic AO principles of fracture management should be applied.

* Anatomical reduction of fracture fragments and restoration of limb alignment
* Preservation of blood supply to bone fragments and soft tissue by atraumatic surgery
* Stable fixation satisfying the biomechanical requirements of the fracture.
* Early pain-free movement and weight bearing of the traumatised limb

In different fracture situations the **priority** given to different principles may vary since a balance must be struck between different principles, particular between anatomic reduction of fragments and preservation of blood supply to the bone. A key question is:

*Does the mechanical advantage gained by manipulation and reconstruction of fragments outweigh the biological cost?*

For simple diaphyseal fractures, reconstruction leads to a large mechanical gain with relatively little biological damage as reduction is straightforward and **load sharing** can be achieved between the implants and the reconstructed bone. Failure to reconstruct and compress a simple fracture can lead to stress concentration on the implant at the level of fracture and subsequent cyclic implant failure. For comminuted fractures, biological damage from fragment manipulation is likely to outweigh any modest mechanical advantage and accurate reconstruction is often best avoided; fractures are treated by restoration of bone length and alignment, and application of robust **bridging fixation** without reconstruction of intermediate fragments. This approach to fracture stabilisation has been described as 'biological' fixation. More load is borne by the implant in the early stages of fracture healing, and hence stronger implants or implant combinations are indicated to reduce the risk of early implant failure.

For articular fractures, accurate reconstruction of articular surfaces and rigid fixation is important to minimise post-traumatic osteoarthritis and joint stiffness, and hence more emphasis is placed on fragment reconstruction. However, the relative benefits and complications of surgery as well as the overall prognosis must still be considered; for some articular fractures immediate arthrodesis or delayed or immediate joint replacement may be considered.

**Biomechanics of fractures and implant systems**

Surgically, long bone fractures can be stabilised using one of three techniques - intra-medullary devices (pins or interlocking nails), plates and bones screws, and external skeletal fixation. Other forms of fixation such as cerclage wire or lag screws may also be used, but they must be combined with one of the three basic techniques. There are a number of basic disruptive forces that act on fractures, and these must be resisted by the fracture stabilisation system. In some cases, it is appropriate to combine implant systems (eg pin and plate) to provide a more stable healing environment. It is also important to carefully consider the anticipated stability of the **bone-implant construct** at the end of surgery; if implants are overloaded, mechanical complications such as implant failure are more likely. This can be avoided by using stronger implants, combining implant systems, or achieving load sharing for simple fractures.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Implant**  | **Bending**  | **Rotation**  | **Axial compression**  | **Tension**  |
| IM pin  | +++ | - | - | - |
| Interlocking nail | +++ | ++ | ++ | ++ |
| Bone plate  | ++ | +++ | +++ | +++ |
| ESF  | + (++) | + (++) | + (++) | + (++) |

*Ability of implants to resist disruptive forces*

**IM pins**

Pins help to align the bone during surgery and resist bending forces well, but resistance to rotation is very poor and hence an IM pin alone would almost never be appropriate for fracture fixation. Pins can be combined with cerclage wire for long oblique fractures, however this is a relatively weak form of fixation. In most cases pins are used in combination with other forms of fixation such as plates or ESF.

**Interlocking nail**

ILNs are essentially a large pin with holes at each end which can accommodate a screw or bolt. Following placement of the nail in the medullary canal, the screws or bolts are drilled through the bone and through the holes in the nail. ILNs resist all disruptive forces reasonably well. Using more modern systems, strong bolts can be used that interlock more securely with the nail, giving a more stable healing environment and lower complication rates.

**Bone plates**

Plates can resist all disruptive forces well, although they can be weakened by cyclic bending forces if load sharing with a reconstructed fracture is not achieved. For comminuted fractures they would often be combined with a pin or a second plate. Caution is needed during application to minimise soft tissue damage which could impede fracture healing or lead to other complications such as infection.

**ESF**

Depending on the frame configuration created, ESF can resist all forces well. However ESF requires much more aftercare following surgery and complication rates can be high compared to internal fixation. Although ESF is still used for some patients, especially juvenile animals, in most cases internal fixation is preferred.

**Clinical assessment of the trauma patient**

A complete work up is essential, including a full history and physical examination and, in most trauma cases, haematology/biochemistry, urinalysis, thoracic and abdominal radiographs. Other diagnostic procedures are performed as required.

Once a patient is stable, radiographs can be obtained of the injured limb. At least two views of a fracture are obligatory. Radiographs should include the adjacent joints of an injured bone, and it may be prudent to radiograph the entire affected limb. Radiographs of the contralateral limb can also be useful for surgical planning. Sedation or general anaesthesia is usually required to obtain good quality radiographs.

# **Assessment of the fracture**

Information from the history, clinical examination, laboratory data and radiographs should be drawn together to formulate a plan of treatment for the patient. This should also include a realistic prognosis for the owner and an estimation of costs.

**Fracture Patient Assessment Score (FPAS)**

This is a simple system which aims to standardise the process of fracture assessment. Three areas - mechanical, biological and clinical factors, ‘MBC’ - are considered. The original FPAS system assigned numerical scores to different factors. However, the numerical scores are not critical and most surgeons use a simple system where the mechanical, biological, and clinical factors are considered and graded as either good, moderate or poor.

### *1. Mechanical factors*

It is important to consider the disruptive forces that will be acting on the fracture site and how these can be neutralised to create a low strain environment. In general negative mechanical factors would dictate use of a **stronger** fixation system. Factors that should be considered include:

* Inherent stability of the fracture
* Whether reconstruction of the bone and load sharing can be achieved
* Bodyweight
* Physical activity level
* Presence of injuries to other limbs

### *2. Biological factors*

This considers the health and healing potential of a fracture. The fracture itself and the overall health of the patient must be considered. Negative biological factors would suggest a fracture may be slow to heal and a more **durable** fixation system should be considered.

Systemic biological factors may include:

* Age of patient
* Concurrent injuries or disease

Local factors may include:

* Quality of the soft tissue envelope
* Location of the fracture on the bone (ie diaphyseal or metaphyseal)
* Presence of infection

### *3. Clinical factors*

The ability of an owner to comply with postoperative instructions and the ability of a patient to cope with aftercare must also be considered. In addition, the surgeon must consider his or her ability to perform the operation successfully, and the owner’s financial limitations.

# **Other key questions**

In order to select the most appropriate method of fracture treatment, a number of key questions should be answered:

* What are the disruptive forces which must be controlled by the fixation?
* What methods of fixation are possible for the fracture?
* Are the principles of fracture fixation being addressed, and how should different principles be emphasized; in particular would reconstruction or bridging fixation be most appropriate (absolute or relative stability)?
* What method of fixation best addresses the biological and mechanical requirements of the fracture, the needs of the patient and needs of the owner?
* What potential problems could arise, and how can these be avoided or managed?
* What is the plan A, B and C?

Once the plan for fracture stabilisation has been established, the surgeon should fully prepare for the operation. Available equipment, operating room set up and anaesthesia should be carefully considered. Regional anatomy and approaches should be revised, and every step of the operation mentally rehearsed. Potential complications should be anticipated. This will ensure surprises are not encountered during surgery, which allows for lower complication rates and improved success.

The surgeon must also plan the postoperative care for the patient. This should include a detailed discussion with the owner regarding analgesia, other medications such as antibiotics, exercise levels, and scheduled check ups. Follow up radiographs should be obtained and appropriate times to document healing and help guide decision making with respect to changes in exercise levels.

**References and further reading**

BSAVA Manual of Canine and Feline Fracture Repair and Management, 2nd Edition (2016). Edited by Gemmill TJ and Clements DN. BSAVA, Gloucester, UK

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