Fracture Management using External Fixators

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*This series of lectures will cover the basic principles of linear external skeletal fixation (ESF), tips for application, clinical applications and complications.*

1. **INTRODUCTION TO EQUIPMENT**

External skeletal fixators (ESFs) consist of three elements: percutaneous transosseous pins, clamps and connecting bars. When the pins are inserted into bone, together, these components are united to create extra corporal frames for the management of fractures and for immobilisation of joints. Let’s consider each element in further detail:

**Pins**

Most pins have a trochar type (or ‘arrow head’), which cuts bone when the pin is advanced and rotated against the bone. Trochar tipped pins may have a smooth shaft (so called ‘smooth pins’) or they may have a thread (‘threaded pins’), which is designed to increase the surface area and friction of the bone to pin interface. The smallest pins used in ESF are fine arthrodesis wires and theoretically, the largest pins available are large intramedullary (Steinmann) pins.

Negative threaded pins are smooth pins into which a thread is cut into the pin tip and positive threaded pins (or ‘positive profile’ pins) have a thread rolled onto the pin shaft, hence the external dimension of the thread exceeds that of the smooth shaft. The bone to pin interface surface area of smooth pins is relatively small and the friction relatively low hence smooth pins have a low resistance to pull out and relatively short longevity before they loosen when they are used in ESFs. Threaded pins have a higher pull out resistance and tend to become loose less quickly and hence are generally preferentially used in ESF. Furthermore, when inserting threaded pins, as the pin rotates, the self-tapping thread actively advances the pin into the bone, making pin insertion controllable and relatively effortless. The pin to thread junction of the negatively threaded pin is a ‘stress riser’ or weak point and pin breakage at this point is a theoretical problem due to mechanical fatigue and failure. In clinical practice, when Ellis pins (which have only a short length of thread) are used and the smooth to thread junction is placed entirely within the bone, pin failure is only rarely a concern. Bicortical negatively threaded pins have recently been designed by Veterinary Instrumentation.

Positive profile pins may be either end-threaded or centre threaded. When inserted into the bone, end threaded pins have a single length of shaft emerging from the skin surface, which interconnects with the ESF. Such pins are termed ‘half pins.’ When the thread of a centre-threaded pin engages the bone, both ends of the pin shaft emerge from the skin surface, on opposite sides of the limb. Both ends of the pin are incorporated into the frame and these pins are termed ‘full pins.’ Positive profile pins have either a fine thread, designed to maximise the pin to bone interface in the cortex (‘cortical thread’) or a course thread, designed for pin insertion in the woven bone of the metaphyses (‘cancellous thread’). The pull out resistance of positive profile pins exceeds that of negative threaded pins. It is important to drill a pilot hole in the bone prior to inserting a positive profile pin to minimise iatrogenic injury.

The shaft of the Imex SK pins is finished to create a roughened surface, which is designed to increase the pin’s ability to bond to adhesive (when used with acrylic connecting bars). Some of the smaller pins have machined grooves designed for the same purpose.
Clamps
Clamps join the pins and connecting bars. Several varieties of clamp are commercially available. The traditional Kirschner-Ehmer (KE) clamps are a simple three-piece (U clamp, bolt and nut) clamp with a threaded, cannulated bolt that accommodates the bicortical pin. There are three sizes of clamp (small, medium and large), each of which can be used with a small range of pins diameters and each of which has its own diameter connecting bar. Small KE splints are suitable for cats and dogs less than 10 kg, medium splints for larger dogs and large splints for giant breeds. KE clamps are relatively weak in mechanical terms compared to newer generation clamps, though the KE clone clamps produced by Veterinary Instrumentation are mechanically superior to the original design. Once assembled on the connecting bar, it is not possible to remove these clamps without entire frame disassembly. Furthermore, it is not possible to place a positive profile pin through an original KE clamp. KE Plus are new generation clamps produced by Veterinary Instrumentation which come in 3 sizes; small, medium, large. They can accommodate positive profile pins. A split KE clone clamp is available from Veterinary Instrumentation, which solves these problems. However, this split clamp is mechanically inferior to the standard clamp and should not be used as a direct substitute in place of normal clamps.

Maynard and Jam clamps are available on the continent and occasionally appear in the clinical literature. These are mechanically inferior to KE.

The Imex SK clamp is a split clamp, which allows clamps to be added and removed from the ESF without disassembly. There are two clamp sizes. A cannulated bolt and washer system accommodates a wider range of pin sizes in each clamp with enhanced grip. These clamps are mechanically superior to KE. Positive profile pins can be readily placed at multiple sites with these clamps and clamps can be added/removed from the connecting bar at any time. Imex SK clamps require 6.3 mm connecting bars and large clamps are used with 9.5 mm connecting bars.

Table 1 IMEX SK™ Fixators: Pin, Rod and Bolt Sizes

<table>
<thead>
<tr>
<th>Clamp Size</th>
<th>Fixator Pin Shaft Diameter</th>
<th>Connecting Rod Diameter</th>
<th>Nut Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini</td>
<td>0.9 – 2.5 mm</td>
<td>3.2 mm</td>
<td>7 mm</td>
</tr>
<tr>
<td>Small</td>
<td>2.0 – 4.0 mm</td>
<td>6.3 mm</td>
<td>8 mm</td>
</tr>
<tr>
<td>Large</td>
<td>3.0 – 4.8 mm</td>
<td>9.5 mm</td>
<td>10 mm</td>
</tr>
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</table>

Securos Secur-U clamps (Millis, Massachusetts) are three-piece clamps (U-shaped component, bolt and head) that can also be added and removed (at any stage) from the ESF during assembly. Positive profile pins can be readily accommodated. Two clamp sizes are available and they are compatible with the small and medium KE connecting bars. Secur-U clamps have superior pin-clamp mechanical strength compared to KE clamps. Purpose designed Secur-U clamps can accommodate an augmentation plate that enhances the mechanical strength of the fixator and can be also used to facilitate fracture dynamisation.

Practical tip
All clamps require a spanner. It is prudent to ensure at least two suitable spanners are kept with each fixator kit!

Connecting bars
Traditional KE splints and Secur-U clamps use stainless steel connecting bars. Smooth ended bars are commercially available. Imperial sized Steinmann pins are mechanically identical and are a less expensive alternative. Small KE uses 1/8 inch and medium uses 3/16 inch. The large system is best used with the recommended alloy connecting bars to minimize frame weight.

The Imex SK system uses relatively large connecting bars, which makes them stiffer than equivalent KE/Securos splints. Imex connecting bars are 6.3 mm (small) and 9.5 mm (large). The bars are available in carbon fibre and titanium (aluminium for the large clamp). These materials are lighter than steel hence there is an increase in stiffness without weight compared to KE. Furthermore, carbon fibre is radiolucent.

Acrylic can be used as a connecting bar, in which case, the need for clamps is obviated. Acrylic splints can be contoured to the body/joint angle. A commercial acrylic kit is available (APEF, Innovative Products, Minnesota), distributed in the UK by Veterinary Instrumentation. Mechanical tests show that a 3-4 inch acrylic APEF bar has comparable strength to a medium KE connecting bar. Free form epoxy putty can be used as a connecting bar. I find this particularly suitable for managing mandibular and maxillary fractures, but concerns with variability of pin to connecting bar security make use of this product a concern for use as the sole connecting bar for limb bone application. ‘Technovit’ or epoxy ESF putty can also be used to make homemade connecting bars. Exothermic reaction can cause bone injury and this should be prevented by maintaining a minimum bone to bar distance and by liquid cooling pins during epoxy cure.

![Figure 1: A modified type II IMEX frame with carbon fibre connecting rods](image)

References


Veterinary Instrumentation Catalogue. Veterinary Instrumentation, Sheffield, UK.
2. **BONE HEALING WITH THE USE OF ESF**

**Fractures – remember to be a gardener as well as a carpenter**
Fractures are usually caused by direct trauma or indirect trauma and the blood supply to the fractured bone is compromised. External skeletal fixation (ESF) is a commonly used, very versatile method of fixation for a wide-range of fracture types. One major advantage of ESF is the ability to take care of the biology of fracture healing whilst creating a stable environment.

**Classification of fractures**
Fractures are classified by several criteria. Firstly, whether there are any associated external wounds. A fracture where the bone has made contact with the atmosphere is termed “open” (old name “compound”) but where the overlying skin is intact, the fracture is termed “closed”. Open fractures are graded on a scale of 1-3:
Grade 1 - bone ends have pierced skin and retracted back into tissues
Grade 2 - open wound exposing fracture site
Grade 3 - major disruption and loss of soft tissues

*Key point: Because ESFs avoid implants at the fracture site, they are often indicated for open fractures. They also allow attendance to open wounds during the healing process.*

**Factors inhibiting vascular response to fracture**
The vascular response is imperative for efficient healing of bone. Several factors may limit the vascular response: the original trauma, careless surgical handling of soft tissues, inadequate fracture reduction and inadequate stabilisation. Thus ESF avoids issues with disruption with the soft tissue envelope of the fracture.

**Bone healing**
The normal sequence of events following fracture involves:
- Haemorrhage and clot formation
- Inflammation and oedema
- Proliferation of cells
- Cartilage and bone formation - callus
- Remodelling of callus

The type of bone healing (primary or secondary) in an individual patient is dependent on the mechanical environment at the fracture site. As stability at the fracture site increases the amount of callus formation will decrease. A fracture that has been anatomically reconstructed and rigidly stabilised with an external fixator will typically heal by primary bone union. However when the fixation is too rigid stress protection of the bone occurs and bone healing may be impeded (in accordance with Wolff’ law). Thus there is a delicate balance between achieving sufficient stability at the fracture site to maintain fracture reduction and yet allowing enough stress to be transmitted to the fracture site to stimulate bone healing.

**Types of callus**
The function of callus is to stabilise fragments to allow lamellar bone to grow and fill fracture gap. The size of the callus is thus related to the stability of the fracture. Three types of callus exist: periosteal, medullary and endosteal. Completely stable fractures should heal without callus formation and this is called primary bone union.
The type of fracture fixation influences the type of callus formed. ESF leads to all types of callus formation. It should be remembered that secondary bone union provides greater strength earlier compared to primary bone union. In addition, there is no disadvantage to secondary bone union.

Factors influencing the type of fracture callus

Factors influencing fracture healing

The important factors which influence fracture healing are the blood supply, the accuracy of reduction and the stability of fixation. Fracture healing times vary with several factors such as the age of the animal, species (cats are generally better at healing bone than dogs), the type of bone fractured (the metaphysis and epiphysis heal quicker than the diaphysis and the type of fracture (simple apposed fractures heal quicker than comminuted distracted fractures). In addition, infection will slow healing as will concurrent systemic disease such as Cushing’s syndrome.

The concept of interfragmentary strain.

Strain is defined as the ratio of “change in length”/“original length”. Or mathematically: 
\[ \varepsilon = \frac{\Delta L}{L} \]

Bone can only form under conditions of less than 2% strain. Each cell can tolerate 2% strain and will continue to form bone, but if this strain limit is exceeded, cartilage or fibrous tissue will form. If we consider cells at a fracture site, as in the figure below, one can see how a larger fracture gap leads to lower strain on each individual cell for a given degree of strain on the whole bone. Thus the “biological” approach to fracture fixation accepts large fracture gaps but optimises blood supply in a stable environment. ESFs fall neatly in to this overall concept.

Enhancing fracture healing by manipulation of ESF frame rigidity

- Staged disassembly or destabilisation

‘Staged disassembly’ and ‘destabilisation’ are synonyms that describe the conversion of a rigid initial fixation to a less rigid form once early bone healing as occurred. The flexible frame so produced allows enough loading at the fracture site to stimulate callus hypertrophy and bone remodelling whilst still protecting the fracture from overloading that might be detrimental to healing. Experimental studies have shown that the optimal
time for staged disassembly is approximately 6 weeks. However the optimum time will be influenced by biological fractures pertaining to the individual fracture such as patient age and general health, soft tissue injury, the presence of infection and the addition of a cancellous bone graft. Destabilisation too early results in unstable fixation with excessive periosteal callus formation and delayed healing.

**Axial dynamisation**

Weight-bearing forces are allowed through the long axis of the fractured bone while controlling bending and torsion. Axial dynamisation is easily achieved with the Securos system using specially designed clamps that slide along the connecting bar whilst still gripping the fixation pin. There is experimental evidence for a positive effect on bone healing.

3. **BASIC BIOMECHANICS: DESIGNING A FIXATOR THAT MEETS THE NEEDS OF THE FRACTURE PATIENT**

**Designing a frame to meet the needs of a fracture patient**

As we plan an ESF frame to manage our fracture patient, we need to consider the following factors:

- Can the fracture be reduced to load-share with the frame? (i.e. is it reconstructable or not?). In many cases, when using ESFs, the answer will be “no”.
- How long will the fracture take to clinical union?

These variables dictate the rigidity and the longevity requirements of our bone-ESF construct. The strength and stiffness of the bone-frame construct determines the deforming forces acting on the fracture site and on the fixator pins. The frame selected must resist these deforming forces such that movement at the fracture site (strain) is sufficiently small to facilitate fracture healing and such that the bone-pin interfaces are not excessively stressed, leading to movement and then to bone resorption and loosening. Biomechanically inadequate frames allow excessive movement, predisposing to premature pin loosening and also to delayed or non-union. Pin loosening is the most common complication of ESF and a main cause of patient morbidity. Consequently, it is important to design and assemble an ESF that meets the minimum rigidity requirement of the fracture and the patient.

**Frames classifications (see lecture)**

Frames can be unilateral, bilateral, uniplanar, biplanar, hybrid (with circular ESF), Hybrid with intramedullary pins.

**Maximising rigidity**

- Each load-sharing fragment should have three pins. (Mechanical tests show that maximum strength is achieved with four pins but this is rarely practical and there is minimal difference between three and four pins per fragment).
- Use the largest pins (hence the largest frame) possible, but do not exceed 30% of the diameter of the bone. (Pin bending strength is proportional to (radius)$^4$ and thus a small increase in pin diameter gives a much large increase in bending stiffness. However, pins larger than 30% of the bone diameter increase the risk of iatrogenic bone fracture).
- Place the connecting bar as close as possible to the limb but not so close as to damage soft tissues. This reduces the functional length and therefore increases the stiffness of pins.
• Place the pins in a ‘near far and far near’ configuration with respect to each fragment and the fracture site. Spacing the pins over the maximum length of fracture fragments increases resistance to deforming forces.
• Use full pins (and hence type II frames) for comminuted fractures (when load sharing will not be possible). Additional connecting bars and creating bilateral and biplanar frames substantially increases frame rigidity.
• For proximal limb fractures, use a tied-in intramedullary pin because it is not possible to apply a bilateral fixator here. Articulate these fractures with additional connecting bars placed diagonally. Tied-in constructs have significantly higher bending strength than type Ia frames.

The factors responsible for increasing the usual predicted time that a fracture will take to reach clinical union include:
1. Skeletally immature patient. (This factor progresses with advancing age).
2. Damage to the soft tissue envelope, e.g. open fractures, severely comminuted fractures, fractures with massive displacement.
3. Infection
4. Additional clinical disease
5. Polytrauma
6. Minimal soft tissue cover (e.g. diaphyseal fractures of the cat tibia).

Hence the frame applied must satisfy our minimum predicated rigidity and longevity requirements taking these factors into account.

NB Despite our best efforts, not all fractures will heal following a single surgery. Font and others (1997) report that non-union occurred in 43% (5/116) of their cases managed with ESF.

References

(Again, most of the evidence for the information in these notes is referenced in this article.)

4. APPLYING AN ESF: TIPS AND TECHNIQUES

Pin placement- safe corridors
Ideally, pins should be placed in the so-called “safe corridors”, which are areas where there is minimal distance between the skin and the underlying bone (minimal muscle mass) and there is no risk of damage to neurovascular structures. The placement of pins is therefore limited by the muscles and neurovascular structures that surround the bone in which the ESF is to be applied and in the upper limb, the proximity of the thoracic wall or the pelvis. Pins placed using safe corridors are well tolerated by the patients and are less likely to loosen over time compared with other pin placement sites as there is less soft tissue interference. These safe corridors should be used whenever possible. Other less than ideal pin placement sites include areas with significant muscle mass (“hazardous” corridors) or those with significant neurovascular structures (“unsafe” corridors). Pins placed in hazardous corridors are likely to cause significant postoperative morbidity and should only be used if there is no alternative safe corridor. Placement of pins in the unsafe corridors should only be considered if there is no other
alternative site and a direct surgical exposure to the area has been performed, thus avoiding iatrogenic injury to any neurovascular structure.

The safe, hazardous and unsafe corridors for the long bones in the dog have been described (Marti and Miller 1994; Marti and Miller 1994)

Preoperative planning
Once the fracture has been studied it is useful to draw a diagram of the frame to be applied so the amount of intra-operative changes can be reduced to a minimum, reducing the intra-operative time and thus patient morbidity. The use of an acetate template where the fracture can be drawn and the frame to be applied superimposed, is useful during frame design.

Steps in frame positioning

Patient positioning
For fractures of the distal hindlimb (distal to the stifle) the author favours the use of the hanging limb technique. This will allow almost complete reduction/alignment of the fracture fragments without the need for significant intraoperative manipulations as well as helping with pin placement as the limb is relatively immobile. In general, the limb is suspended to the theatre ceiling and the surgical table lowered so the weight of the animal is hanged from the fracture limb and thus applying traction at the fracture site and therefore obtaining spatial reduction. A system that allows the limb to be lowered after the placement of the first pins will allow intra-operative checks to ensure there is no interference with joint movement.

For fractures of the proximal hindlimb (femur) the hanging limb technique is not suitable and therefore the patient is best placed in lateral recumbency. Most fractures in the femur where an ESF is to be applied will be complex and will require the use of an intramedullary pin (in order to increase the stiffness of the frame) and, in general, a direct approach to avoid unsafe pin placement is preferred.

Palpable anatomical landmarks are useful to ensure correct pin placement. A hypodermic needle can be used to aid with the location of the fracture site to avoid inadequate pin placement (too close to a fissure/fracture line).

Techniques for pin placement
When using the hanging limb technique, the pins to be applied further away from either side of the fracture are applied first, ideally parallel to the adjacent joints. The connecting bar(s) is then applied, thus partially stabilising the fracture. The limb can then be lowered to the surgical table so limb alignment can be checked prior to further pin placement. Once we are happy with the alignment the limb can be repositioned again and the remaining pins applied.

A relatively large stab (0.5 cm) incision through the skin and subcutaneous tissue prior to pin placement is recommended to avoid excessive soft tissue drag during pin insertion and to allow early drainage.

It is important to protect the pin-bone interface to minimize postoperative pin loosening. Threaded pins are less likely to loosen over time compared with smooth pins and are recommended in most situations (Anderson et al., 1993). It is important to minimize the risk of bone thermal necrosis during pin application and to minimize bone microfractures at the pin-bone interface. Pre-drilling with a drill which is slightly smaller (0.1 mm) than the pin to be applied has been shown to significantly reduce the amount of microstructural damage as well as to reduce the risk of thermal damage, thus
improving the pin-bone interface (Clary and Roe, 1996). The use of a slow drill for pin insertion will also reduce the risk of thermal necrosis compared with a high-speed drill. Irrigation with sterile saline will also help to dissipate any generated heat. The use of hand pin placement is not advocated, as there is an increased risk of structural damage to the bone due to excessive pin wobbling leading to premature loosening.

The angle of insertion is not that critical if threaded pins are used as the threaded design account for the pullout properties of such pins. Threaded pins are usually inserted at perpendicular angles in relation to the long axis of the bone as this maximises the number of pins per fragment that can be applied.

It is important to ensure the clamps are not in direct contact with the skin throughout the range of movement as this will invariably lead to skin irritation, licking and patient discomfort. A recommended distance is about 1cm from the skin to account for postoperative swelling.

**Post-operative adjustments**
Following application, some degree of adjustment can be performed after evaluation of the postoperative radiographs. Half-pins that do not fully penetrate the transcortex can be further inserted to ensure adequate bone purchase. Half-pins that are excessively long can be withdrawn slightly although this is best avoided as will significantly damage the pin-bone interface.

Loosening of the connecting bar and minor adjustments can be performed to improve limb alignment, especially if the joints above and below are not aligned. Valgus and varus deviation is more critical compared with caudo-cranial deviation and this should be carefully evaluated. A 50% of overlap of the fracture ends will ensure satisfactory healing.

**Removal of frames**
Frame removal should be carried out once the clinician is sure the fracture is adequately healed. Loosening of the clamps and manual assessment is useful to determine the strength and stability of the healing callus. A gradual, staged disassembly can be considered to accelerate callus maturation (Larsson et al., 2001). It is advisable to limit activity following frame removal for four to six weeks to avoid re-fracture at the level of the original fracture or at the holes left by the pins following removal as they can act as stress risers.

5. OTHER ESF TYPES

**TIE-IN FRAMES**
Femoral fractures do not lend themselves to the application of biplanar or bilateral frames due to the proximity of the thoracic wall or the proximity of the pelvis and therefore frame application is limited proximally to the lateral aspect although distally full pins can be applied through the femoral condyles. The femur is also covered by well-developed muscle groups that are best avoided during pin placement, as this will significantly increase postoperative morbidity. The areas for safe pin placement are limited, in the femur, to the area immediately distal to the greater trochanter proximally and the region of the femoral condyles distally.

The use of an intramedullary pin tied-in to the external frame is very helpful to overcome the limitations imposed by the local anatomy. It has been shown that the addition of a tied-in pin significantly increases the stiffness of a ESF frame (McPherron, Schwarz, and Histand, 1992). The intramedullary pin is placed by a minimal approach to the fracture site, avoiding significant disruption of the fracture fragments and limiting
the amount of iatrogenic soft tissue damage. The intramedullary pin allows spatial reconstruction of the fracture and helps maintain reduction during frame application. Cutting the distal tip of the pin is useful to avoid intra-articular penetration of the pin. The pin can be connected to the lateral aspect of the frame and also medially if a full pin is applied distally or be left standing (without being tied-in). Earlier frame removal can be considered once there is sufficient stabilising callus to counteract compression and torsional forces (because of the inherent stiffness of the intramedullary pin against bending forces). The stiffness of the construct is directly related to the size of the intramedullary pin, however an excessively large intramedullary pin will limit the application of the transosseous pins. An intramedullary pin that does not exceed 60% of the diaphyseal-medullary cavity will allow for adequate room for pin placement in the metaphyseal regions without causing significant interference, providing the pins are angled slightly to avoid hitting the intramedullary pin.

HYBRID FIXATORS
These frames can be either an additional bar (e.g. type I-II hybrid linear ESF) or a hybrid linear-circular ESF. The type I-II hybrid has been used for proximal long fractures as in the femur. The hybrid linear circular ESF is most useful for juxta-articular fractures such as found in the distal tibia and radius. These frames are limited to the distal limb due to the circular ring.

ACRYLIC FIXATORS
The use of plastic tubing injected with liquid acrylic as a connecting bar (APEF system) or the use of moulded acrylic or epoxy connecting bars allows the use of free-forms configurations, especially useful for humeral fractures and mandibular fractures (Guerin et al., 1998; Roe and Keo, 1997). This allows the placement of pins with a greater degree of freedom as they can be placed in multiple planes, thus allowing complex frame constructs that will not be possible if all pins were limited to a single plane of application.

An exothermic reaction will occur during the curing process of acrylic bars and this is directly related to the diameter of the bar. The generated heat can interfere with the pin-bone interface and can lead to thermal necrosis (leading to premature pin loosening). New “cold” acrylics and Epoxy can be used as safe alternatives.

An alternative is the use of bent stainless steel connecting bars and the use of traditional clamps although this requires careful bending of the bar and limits the number of pins that can be applied. A bent bar does not allow the use of a clamp in the regions of sharp bends and in these places it is best to use acrylics as “clamps”. Notching the pins slightly will increase the gripping and will limit pin slippage.

TRANSARTICULAR FRAMES
Transarticular frames are most commonly used on the management of distal limb injuries such as shearing injuries, traumatic luxation of the carpi and tarsi, collateral ligament injuries and arthodesis where other alternatives are not suitable (e.g. significant shearing injury with gross contamination and where there is inadequate soft tissue coverage) (Benson and Boudrieau, 2002). Occasionally they are used in the upper limb for further protection of soft tissue repairs (e.g. patellar tendon repairs) or for complex fractures where increased stiffness is required.

It has been shown that immobilisation of joints is detrimental for the health of the articular cartilage (Keller et al., 1994), as well as for the surrounding ligamentous structures. Ideally the period of immobilisation should be kept to a minimum and the joint immobilised at an angle that mimics that of weight bearing whilst standing. It is
preferable to use hinged frames that allow controlled or complete movement in the craniocaudal plane whilst providing collateral support to minimise theses changes.

- Hinged fixators (e.g. those produced by IMEX) (that allow some range of movement) overcome some of the detrimental effects of long-term joint immobilisation and can be particularly useful for the management of collateral ligament injuries. Several hinges are commercially available these days. The only consideration whenever they are to be applied is that the hinge(s) should be exactly located at the instant centre of motion (point of no translation throughout the range of joint motion) for the hinge to be functional and to prevent catastrophic failure. This is achieved by careful intra-operative assessment and manipulation of the joint through the range of motion prior to final pin placement.

6. CLINICAL APPLICATIONS OF LINEAR AND HYBRID ESF (see lecture for examples)
Remember selection of a specific ESF type is directly related to the fracture type and patient factors (i.e. if it is suitable for an ESF). The less a fracture is load sharing the more rigid a frame is required

**FEMUR**

- Type Ia and b in cats
- Hybrid I-II
- Not type II and III due to abdominal wall interference with bilateral frame.
- Tie- in with and IMP (as described above)
- Transarticular (for failed MPL surgery, patella tendon rupture) or juxta-articular fractures
- Pins lateral and craniolateral- remember safe corridors

**TIBIA**

- Ideal bone for ESF- pins placed medially-safe corridors
- Type Ib and III- half pins cranial
- Suitable for all frame types except tie-in

**TARSUS**

- Transarticular frames- most applicable for tarsal fracture, luxations, shear injuries, soft tissue protection (e.g. Skin flaps) and arthrodesis
- Less rigid frames e.g. Type Ia for simple luxations in dogs/cats. More rigid- Type II/II modified with A frame in bigger dogs.

**FOOT**

- Good for multiple metatarsal fractures e.g. SPIDER (see lecture)

References


7. **POST-OPERATIVE CARE OF ESFS**

*Immediate post-operative period*

**Radiography**

Orthogonal postoperative radiographs should be critically assessed. It may be necessary to take views at different angles to avoid superimposition of bone and connecting bars. Carbon fibre connecting rods have the advantage of being radiolucent and allow a better assessment of fracture reduction and alignment.

- **Alignment** (50% overlap, and correct proximal/distal alignment)
- **Frame and fixation pins** (30% width of bone, bar not too close to soft tissue, no pins in joint, pins bicortical)

**ESF care**

- All clamps should be retightened, implants cut as short as possible to reduce injuries and the clamps and sharp pin-ends should be covered with a self-adhesive tertiary bandage layer. Avoid putting this bandage close to the skin-pin interface – it will cause problems. The gap between the skin and the connecting bar should be packed with soft padding (sponge, swabs, soft bandage or cotton wool) and for distal limb fractures, the entire limb including the foot should be dressed overnight, to reduce swelling.

- Twenty-four hours following fracture repair, a pressure dressing is rarely required, though sometimes the dressing is required for longer (e.g. in cats) to control foot swelling. Analgesia (an opioid in addition to NSAIDs) should be given appropriately. I always use an opioid for at least the day following surgery.

*Long term post-operative period*

**Radiography**

- Look for evidence of smoothing of sharp bone fragments, indicative of bone remodelling and eventual callus and bridging
- Check for lucency around implants. Lucency implies loosening. Loose implants should be removed (and replaced, if necessary for fracture stability).

At 4-10 weeks, depending on the patient age, type of fracture, etc., radiographs should show evidence of healing (endosteal, intercortical and periosteal callus). If so, loosen ESF and check for clinical stability of fracture site. If both are present, the ESF can be destaged by removing some pins, and/or a connecting bar. Destaging at four to eight weeks can accelerate healing. Timing of staged disassembly is controversial and in clinical cases, one never knows if the action truly accelerates healing. There is nothing to be gained by destaging too soon! The window of opportunity is approximately four to six weeks following fracture repair and the benefit is lost after 12 weeks (Egger and others 1993). If loose pins are identified during physical checks and if frame destaging is planned, the loose pins should be removed preferentially. It is preferable to retain implants that protect against rotational deformation at this early stage of fracture healing.

For many fractures stabilised by ESF, a single check film at four to six weeks postoperatively indicates immature healing and a subsequent film taken four weeks indicates sufficient healing for ESF removal. Sufficient healing means (a) mineralised callus that bridges all the fracture lines on both orthogonal views (i.e. all four cortices for a simple two piece fracture) or (b) bridging callus on three of four cortices. It may be helpful to remove connecting bars or to take oblique views to evaluate the fracture(s). **There must also be clinical union.**
ESF Aftercare

A Care Sheet for clients is helpful, detailing:

- Strict rest
- No interference with ESF or limb by owners (provide collar)
- Medication
- Watch for reduced limb use
- Swelling
- Discharge
- Revisits once weekly required
- Repeat radiographs required at four weeks and whenever there is a problem.

A veterinary check should occur each week to check for pin site problems, for limb use, for wound healing etc. Old recommendations indicated that clamps should be retightened. This is unnecessary with modern clamp designs. Normal healing is associated with a serum seal forming around pin sites. This does not need cleaning. It is useful to keep hair short over these pins. Animals should be using their limb well.

Pins placed through moving skin or muscle bellies have a watery discharge – clients should clean surrounding skin with sterile saline every day. The bacterial load on the surrounding skin can be reduced in problem patients by applying topical antibacterial agents (e.g. Fucidin/derm). A copious pin discharge is almost due to pin loosening and a radiographic assessment is indicated.

Once there is complete healing, the ESF is removed. Fractures managed with ESFs should be those in which complete healing is anticipated within 12 weeks. Bone pin interfaces do not usually last longer than this and implant loosening is associated with patient morbidity. For these reasons, ESF is not always the most prudent fracture management method for patients with modest healing potential (e.g. elderly animals). In such cases, consideration should be given to the routine use of fracture healing stimulation, such as cancellous bone grafting.

References


8. COMPLICATIONS

- Soft tissue impalement
- Failure to maintain stability
- Infection
- Pin tract discharge (major and minor)