External skeletal fixation in large animals: A review

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Abstract External skeletal fixation (ESF) was first adapted for veterinary medicine in 1934; this fixation method consisted of devices for stabilizing musculoskeletal injuries, such as fractures, dislocations, tendon ruptures, and angular deviation; using transcortical pins or wires connected in sidebars or cast to cover the region of instability. The evolution of orthopedics in veterinary medicine, together with the development of diagnostic imaging and the field of anesthesiology, has allowed a substantial increase in success rates in cases of fractures in animals. However, orthopedic cases in large animals, especially, are still challenging due to the unique characteristics of the species, which are associated with bone regeneration and depend on the specific type of lesion and the use of implants that adequately support the stress distribution. External fixation techniques in large animals are plausible strategies for cases of open and/or comminuted fractures of long bones, and the literature shows that these approaches are successful. The objective of this study was to conduct a literature review of the possible configurations of ESF used in large animals and their indications. In addition, we aimed to determine the factors that influence the success rate of these techniques, as well as the advantages and disadvantages, to determine whether the use of ESF in orthopedic patients is a reasonable option for the management of certain diseases.

Keywords: orthopedics, veterinary medicine, osteosynthesis, fractures, metallic implants

1. Introduction

The veterinary orthopedics has evolved substantially in recent years, with emphasis on the invention and improvement of new surgical techniques, advancements in the research and production of new orthopedic materials/implants, and the ease of sharing experiences and knowledge among professionals working in the field of veterinary medicine (Auer 2023). Allied to the technological/scientific expansion of anesthesiology and diagnostic imaging, areas related to success rates in orthopedic surgeries were identified.

Although the advances described corroborate the attempts and techniques applied, fractures in large animals remain challenging. The differences between species are associated with bone regeneration and depend on the specific type of lesion and the use of metallic implants, which occasionally tend not to support the proper stress distribution, causing failure of these implants. Factors that directly reflect the conduct of veterinarians regarding the decision of the techniques and management used for certain orthopedic traumas.

Given this scenario, the treatment of large animals (horses and ruminants) with a diagnosis of long bone fracture tends to consider the cost of treatment, the success rate, the associated economic and genetic value and the location and configuration of the fracture (Anderson and Jean 2008). An alternative that has been developed and improved in human medicine since the 1840s and has been adapted to veterinary medicine since 1934 is the use of external skeletal fixation (ESF) (Pettit 1992). These methods consist of stabilizing a musculoskeletal injury (fractures, dislocations, tendon ruptures, angular deviation) using transcortical pins or wires (Kirschner) externally connected by sidebars covering the region of instability (Lewis et al 2001). The rigidity of the fixation must be sufficient, but not excessive, to maintain the alignment of the fracture so that repair is not inhibited (Calhoun et al 1992). Ideally, the fixation method should provide adequate stability to maintain the alignment of the bone fragment while allowing micromovement at the fracture site to allow bone healing (Singh et al 2007).

The ESF can be applied using the reduction of closed or open fractures, limb deformities, pseudarthrosis, and arthrodesis and is often used for highly comminuted fractures that cannot be reconstructed anatomically (Nagar et al 2019; Pentecost et al 2016). This method facilitates the management of associated soft tissue injuries, making it the treatment of choice in patients with open fractures. It generally associated with shorter surgery times and less trauma than is internal fixation. However, this approach requires more specific postoperative care (Dudley et al 1997; Nagar et al 2019).
The objective of this study was to conduct a literature review of the possible configurations of ESF in large animals, as well as their indications. In addition, the factors that influence the success rate of these techniques, as well as the advantages and disadvantages.

2. Structural Configurations of ESF

The ESF can be employed using three types of constructions: transfixation casting, external fixators commercially available, or pinning with acrylic polymer sidebars (Auer 2019; Vogel and Anderson 2014). The structure of an external fixator is determined by the number of distinct sides of the limb from which it projects (unilateral or bilateral) and by the number of planes it occupies (uniplanar or biplanar) (Auer 2019; Palmer 2012). The anchorage consists of pins, which are inserted at different angles so that when the lateral rods, characterized as interconnecting structures (longitudinal bars), are placed, they do not move.

Unilateral-uniplanar (Ia) or biplanar (Ib) ESF consists of the construction of one or two sidebars, in which threaded pins are inserted into the near and far cortical bone without crossing the skin that covers the far cortical, projecting into a side of the limb or both, but are restricted to one plane. Bilateral uniplanar structures (type II) project from both sides of the limb (180° to each other) but are restricted to one plane (usually mediolateral). Bilateral biplanar ESF (type III) are three-dimensional structures whose pins are externally interconnected by three sidebars, projecting from two different sides of the limb and occupying two planes (Auer 2019; Palmer 2012; Wright 2022). Biplanar ESF exhibits greater sagittal stability and better bone healing than uniplanar fixators (Figure 1). In humans and small animals, these three-dimensional configurations optimize the resistance to torsional, shear, and compression forces to protect the bone from fracture propagation through the posterior holes (Lewis et al 2001; Wright 2022).

Circular ESF are often referred to as the Ilizarov system (Russian inventor Gavriil Ilizarov) and consist of tensioning circular rings to Kirschner wires (K-wires), which pass through the bone (Figure 2). This fixator is used when there is a large loss of bone tissue and/or there is contamination of the fracture focus. The advantages of circular ESF include minimal bone perforation for the K-wires to pass through, the possibility of obtaining high stiffness even in poor-quality bone, allowing the patient to perform full load immediately after surgery, and allowing for variation in the stiffness of the bone, fixation, and alignment of the limb during treatment. In animals with high weight, such as adult cattle and horses, this technique was not effective (Camacho et al 2012; Vogel and Anderson 2014).

Figure 1 Bone models with different configurations of linear external fixation. Uniplanar, unilateral, type Ia linear external fixator (A). Uniplanar, bilateral, type II linear external fixator (B). Biplanar, bilateral, type III linear external fixator (C). Credits: Medical Illustrations Rodrigo Tonan.

The technique of transfixation casting may be indicated for comminuted metacarpal/metatarsal fractures, fractures of the proximal and middle phalanges, and articular fractures (Figure 3). This consists of placing two or three proximal pins, proximal from the fracture focus, associated with the pins distal to the fracture, promoting symmetrical stress distribution (Auer 2019; Rossignol et al 2014; Wright 2022).
In addition, a system identified as a sleeve for pins, already used in horses, can decrease the stress at the bone/implant interface, allowing small movements of the pin within the sleeve, thus preventing bone lysis around the pins, and possibly leading to loss of stability. The recommendation for the use of proximal pin alone or in combination with distal pins depends on the type of fracture and which bone is affected (Rossignol et al 2014; Vogel and Anderson 2014). Finally, the cast is placed over the pins, allowing the metal to penetrate its layers. This approach is considered a good method of fixation due to the absence of distraction of the fracture and fragments and lack of force at the fracture focus. However, complications such as the formation of bone sequestration around the pins, instability of the pins, osteomyelitis, and breakage of the pins may occur (Vogel and Anderson 2014).

Figure 2 Illustration of a bone model with a circular external fixator (Ilizarov). A. Detail of the passage of Kirschner wires through the cortices, externally attaching to the bone, on the circular rings. Credits: Medical Illustrations Rodrigo Tonan.

3. Factors that influence the success rate of ESF

The fundamental principles aimed at minimizing the risks and complications include, first, adequate clinical evaluation of the patient and accurate diagnosis using high-quality orthogonal radiographic or tomography for appropriate preoperative planning. Next, strict adherence to antisepsis and asepsis techniques, as fixation pins penetrate the skin and break physical defense barriers, which can cause contamination, inflammation, and consequent premature failure of the pins (Anderson and Jean 1996; Guerin et al 1998; Palmer 2012).

Knowing the relationships among bone, implants, biomechanics, and the material characteristics of ESF is essential for the proper application. Fracture stabilization by ESF depends on: (1) the characteristics of the bone, specifically the density as a percentage of lamellar bone, porosity, geometry, anatomical position, and the fracture configuration; (2) the material properties of the fixator components; and (3) the configuration of the external fixator, including the design of the pins and sidebars (Anderson and Jean 1996; 2008).

The design of the implant and the position of the insert in the fixator configuration significantly affect the strength and rigidity of the construction. The pin-bone interface is the most fragile point of all external fixation techniques, and premature failure of the transfixation screws can occur in these portions; this failure is considered the most common complication (Elce et al 2006; Wright 2022). Positive profile pins (with an external thread diameter greater than the core diameter) have higher stiffness than negative profile pins and are currently recommended by the literature for the construction of ESF in large animals (Auer 2019; Lescun et al 2007; Lewis et al 2003; Wright 2022) (Figure 4).
In cases of transfixation casting, the authors suggest that the pins be located in the bone epiphysis to reduce the risk of catastrophic fractures (Joyce et al. 2006; Lescun et al. 2007; Rossignol et al. 2014; Williams et al. 2014; Wright 2022). The use of three pins is recommended to maximize stiffness while preserving bone strength. It is essential that criteria such as patient size, weight, bone affected, diameter and location where the pin will be inserted in the bone are considered to determine the number of pins to be used in the configuration of choice (Wright 2022).

![Dorsal palmar radiography view of a sagittal fracture in the proximal phalanx of a horse to which transfixation casting was applied.](https://www.malque.pub/ojs/index.php/avr)

**Figure 3** Dorsal palmar radiography view of a sagittal fracture in the proximal phalanx of a horse to which transfixation casting was applied.

### 4. Pros and cons of ESF

The advantages of using ESF include the early return of the function to the affected limb, less damage to the blood supply at the fracture site, and ease of management and/or treatment of wounds with soft tissue involvement; additionally, ESF is considered a good option for patients at risk of infection and preserves the biological mediators that stimulate osteogenesis. In addition, these devices enable a variety of configurations for comminuted fractures, allowing adjustment of the rigidity of the fixation without requiring another surgery; moreover, it is easy to remove the implants after bone regeneration, and relatively few complications can result from the implants (Anderson and Jean 1996; 2008; Vogel and Anderson 2014).

![Schanz pins are used for application in external skeletal fixations with positive and negative profiles.](https://www.malque.pub/ojs/index.php/avr)

**Figure 4** Schanz pins are used for application in external skeletal fixations with positive and negative profiles.
The disadvantages of ESF include the following: suboptimal fracture reduction, effective anatomical alignment, absence of interfragmentary compression (characterizing relative stability), restricted joint movement, and less rigid stabilization of the affected bone compared to plates and screws. The pins and wires penetrate the soft tissues and injure them, forming “pin trails” that persist for prolonged periods. In addition, these structures are often heavy and not always well tolerated (Anderson and Jean 1996; 2008; Vogel and Anderson 2014).

5. Application of ESF in orthopedic cases

Due to advances in veterinary care and the evolution of orthopedic procedures and implants, it has become possible for fractures in large animals to be repaired with satisfactory results (Glass and Watts 2017). Success in orthopedic cases is highly dependent on immediate emergency care associated with adequate planning of the course of action so that the focus of the fracture can be protected and immobilized, regardless of the type of treatment, preventing further injury to adjacent tissues (Artioli 2013; Melo et al 2008).

According to Costa and Neto (2007), immobilization should be maintained until satisfactory repair of the lesion. Just the cast is still frequently used in horses and cattle, especially when the zootechnical value of the animal and possible postoperative complications are key factors in the decision regarding the type of treatment (Anderson and Jean 2008). For fractures in calves, where the cortical bone is thin, external immobilization with casting becomes the main indication, as well as in some cases in horses, such as in luxation, when the cast may or may not be associated with another fixation technique (Marval et al 2004; Melo et al 2008).

In a study involving humans with Achilles tendon rupture, immobilization was shown to be as efficient as surgical treatment (Costa and Neto 2007). Câmara et al (2014) reported that, in cattle with distal fractures below the carpal or tarsal joints, conservative treatment with casting was the method of choice in 17 of the 22 cases studied.

There have been reports of favorable cases of the use of ESF in small ruminants, as the behavior, size, and weight of these animals make them good candidates for these surgical treatment methods (Figure 5), even in cases of fractures of proximal bones, such as the humerus and ulna (Kaneps 1996; Parettsis et al 2016; Vechiato et al 2009). However, the application of ESF in fractures of proximal bones, especially the humerus, is usually limited to the type I configuration or the combination of type I fractures in the proximal region and type II fractures in the distal region has been used in small animals (Simpson 2004).

**Figure 5** Complete transverse fracture of the third and fourth metacarpal bones in a two-month-old lamb. The immediate preoperative period (A). Uniplanar, bilateral, type II linear external fixator was applied, (B). Radiographic follow-up after one month, an additional interconnecting bar was applied (C), and two months after removal of the device (D).

Janicek et al (2013) evaluated the complications of immobilization on the fetlock joints in 398 horses. The casting was performed only with bandages, associated with foam and a thin layer of polyurethane. The positions in which the limbs were maintained, which varied between extended, neutral, and semi-flexed, were also compared. At the end of the study, the authors concluded that 197 animals had complications, 34% of which occurred in animals with casting associated with bandages and 52% of which were treated with casting associated with foam and polyurethane layers. Complications occurred in 71% of the animals immobilized in the semi-flexed position, 48% of the animals in the neutral position, and 47% of the
animals in the extended position. The main complications cited by the authors were skin lesions, especially on the palmar/plantar surface of the fetlock, and a fracture related to the casting was observed in one animal.

Rossignol et al (2014) reported 11 cases of distal fractures in horses treated with transfixation casting. Nine animals fully recovered within eight weeks. For the authors, it prevents sliding and breakage of the pins, allowing the technique to be used successfully. Transfixations with pins and sidebars have the same indications as transfixation casting; on the other hand, they allow for the constant evaluation of soft tissue injuries and the alignment of the distal and proximal fragments of the fracture. The pins must be inserted at different angles so that when the lateral rods are placed, they do not move.

Lesun et al (2007) reported their experience in 35 cases of distal limb fractures (27 adult horses and eight foals) treated with transfixation casting in three Veterinary Teaching Hospitals between 1994 and 2004. These included 15 cases of fractures of the third metacarpal/metatarsal bone, 12 cases of the proximal phalanx, and eight cases of the middle phalanx; nine of these were open fractures, and 31 were comminuted. In 27 of 35 horses (77%), the fracture consolidated, and the animals survived. The fractures included 10 of 15 fractures of the third metacarpal/metatarsal, 11 of 12 proximal phalanx fractures, and six of eight middle phalanx fractures. The results indicated that the transfixation casting may be successful in the treatment of fractures distal to the carpal or tarsus in horses, also demonstrating that this is the most appropriate technique for comminuted fractures of the proximal phalanx.

The use of a circular ESF is less common in large animals than in small animals (cats and dogs). This is because the hardware systems must be much larger in size and strength to support greater body weight (Cervantes et al 1996; Singh et al 2007). However, there have been reports of cases in which circular ESF was well tolerated in ruminants (up to 18 months of age) and in cases of exposed fractures of the radius and ulna, proximal third metacarpal epiphysis and tibial shafts, demonstrating sufficient rigidity to maintain fixation (Aithal et al 2007, 2010).

The hybrid ESF are combinations of circular and linear skeletal fixators and has been studied in large animals because these models can provide the good biomechanical properties and resistance to stresses, thus reducing the potential risk of implant failure (De Godoy et al 2009; Singh et al 2007). In an ex vivo study of tibiae from adult buffaloes, comparing the biomechanical properties of hybrid ESF, bilateral linear external fixator and circular four-ring external fixator, it was concluded that this system was more resistant than was the bilateral linear fixator (Singh, et al 2007). A case of a five-month-old foal with a Salter–Harris type II fracture in the proximal tibia was described as successful with hybrid ESF, highlighting that this approach is a plausible treatment option. The authors described that the device was removed 60 days after radiographic confirmation of healing (De Godoy, et al 2009).

The biological and mechanical environment at the fracture site determines bone healing. This, in turn, is affected by several factors, such as age, weight, behavior and general health, location and type of fracture, severity of soft tissue injury, presence of bacterial contamination, and degree of movement at the fracture site, making the recovery process in cases of bone discontinuity quite complex.

6. Conclusions

The use of ESF has been shown to be a reasonable option for the management of certain types of fractures in large animals and is currently more common for foals, calves, and small ruminants. Identifying the acting forces is essential for estimating the feasibility of using the technique and which configuration to use, in light of the size and behavior of the patient.

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Ethical Considerations

Not applicable.

Conflict of interest

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