II. REVIEW OF LITERATURE

The available literature related to the study of different configurations of external skeletal fixators for radius fracture treatment in dogs is reviewed under following headings.

2.1 Incidence of fracture

Phillips (1979) in a study recorded 80 per cent of fractures in animals less than three years old and most common in less than six months of age (28.60 %). Males were more commonly involved than females and the author reported an incidence of 17.3 per cent of radius and ulna fracture in dogs. The author further opined that, fracture of radius and ulna and tibia to be more common in dogs.

Carrig (1983) stressed the importance of forelimb of the dog as a main weight bearing organ and reported that it experienced trauma frequently leading to fracture.

Singh et al. (1983) observed higher incidence of fracture among dogs of the age group of 0 to 1 year followed by those between 1 to 3 years, 3 to 6 years and above 5 years. They also reported that males had higher incidence of fracture than females.

Thilagar and Balasubramanian (1988) in a retrospective study of 204 cases of long bone fracture in dogs reported higher fracture incidence of radius and ulna (31.40 %) followed by that of tibia and fibula (30.40 %) and femur (14.70 %).

Balagopalan et al. (1995) in a survey of 208 cases of fracture in dogs reported highest incidence of fracture of long bones. Among different breeds Alsatian dogs stood
highest (27.90 %) followed by Doberman Pinscher (17.80 %), Non-descript breed (17.30 %) and Pomeranian (15.40 %). They also reported that the incidence of fracture in dogs was more in the age group between 3 and 6 months (30.80 %) followed by 0 and 3 months (27.99 %).

Aithal et al. (1999) studied 402 cases of fractures in dogs and reported the highest incidence in non-descript dogs. An incidence of 54 per cent was seen among young animals aged less than one year followed by those of the age group of 1-3 years (35.52 %), 6-12 months (20.40 %), 3-6 months (18.64 %), less than 3 months (14.6 %) and above 3 years of age (10.83 %). Male dogs were affected more (63.0 %) compared to female dogs (37.0 %). They also reported the highest incidence of fracture in femur followed by tibia and fibula and radius and ulna.

Rao et al. (1999) conducted a survey of 5,328 cases of canine fractures and reported that, approximately 83 per cent of fractures were seen in dogs of 3 years age. Among the different breeds German Shepherd 26.8 per cent, Doberman 11.2 per cent, Great Dane 7.1 per cent, Labrador Retriever 6.6 per cent, Pomeranian 9.7 per cent, Dachshund 8.2 per cent, Cocker spaniel 3.6 per cent and Non-descript 27.10 per cent were recorded. They also reported that, the fracture was more in males (66.12 %) compared to females (33.88 %). In their survey, they reported a higher incidence of femur fractures which was about 21.39 per cent and tibia and fibula fractures was about 17.69 per cent and radius 14.58 per cent.

Rani et al. (2004) studied 85 cases of fracture in dogs and observed that the incidence of fracture was more common in younger animals group less than one year of
age (58.82 %). Fracture incidence was highest in the age group between 7 and 9 months (22.35 %) followed by 4 and 6 months (16.47 %). Incidence of fracture was higher in males (71.76 %) than in females (28.24 %) and maximum fractures were recorded in radius and ulna (29.41 %) followed by femur (28.23 %) and tibia (24.5 %).

2.1.1 Aetiology

Ness and Armstrong (1995) reported fractures of radius and ulna to be the most common in dogs and were usually due to road traffic accidents although kicks, bites and crushing injuries can also be responsible.

Aithal et al. (1999) reported that the major cause for fracture of radius and ulna was falling from a height (53.1 %) and automobile accidents (34.69 %).

Rao et al. (1999) recorded the cause for long bone fracture in canines, which included road traffic accidents (22.66 %), fall from height (43.06 %), animal interaction (11.73 %) and crush injury (22.54 %).

Rani et al. (2004) observed that fractures in dogs occurred due to automobile accidents (68.24 %) and falling from a height (31.76 %).

2.1.2 Type of fracture

Aithal et al. (1999) reported 50 per cent oblique fractures, 20.61 per cent comminuted fractures, 33.33 per cent transverse fractures, incomplete fractures of 4.55 per cent and 1.52 per cent others among the 402 cases of fractures of radius and ulna.
Ozsoy and Altunatmaz (2003) reported that out of six cases of radius fracture three were fractured at the mid-diaphysis and other three were fractured at distal diaphysis.

Milovancev and Ralphs (2004) reported that fractures of radius and ulna were commonly seen in the small animal population and diaphysis as the most common site in the bone.

Rani et al. (2004) recorded 45.88 per cent of transverse fractures followed by 42.35 per cent of oblique fractures among the fractures of radius and ulna. Diaphyseal fractures were common in the distal shaft (40.0 %) of radius and ulna.

Rovesti et al. (2007) studied 49 cases of radial fracture and observed that 20 were open and 29 were of closed type. 17 cases had comminuted type of fracture.

2.2 Fracture biology and biomechanics

Nunamaker (1985) explained that bone as an osseous structure, could be loaded with tension, compression, bending, shear, torsion or a combination of these forces. If the magnitude of the applied load slightly exceeded beyond the elastic limit, catastrophic failure take place.

Johnson and Hulse (2002) reported that bending caused a transverse fracture on the tension side and slight oblique fracture on the compression side of the bone. Axial compression caused an oblique fracture. Combination of axial compression and bending caused oblique comminuted fracture. Torsion caused a spiral fracture, whereas high energy force caused a comminuted, non-reducible fracture.
Hulse and Hyman (2003) observed that bones got fractured when extrinsic or intrinsic forces were applied and both elastic (reversible) and plastic (irreversible) deformation occurred before breakage. In an oblique fracture, shear and compressive forces predominated. In transverse fracture, rotational or torsion forces predominated.

2.3 Fracture healing mechanism

Heim et al. (1992) reported that, axial compression in a simple transverse fracture by stiff external fixator could result in primary fracture healing as in plate fixation. While complex fractures with external fixation could heal by means of callus formation as with the case of medullary nail. A fracture, which was rigidly stabilized, showed a direct healing characterized by minimal callus formation without any resorption at the ends of the fragments leading to bone formation. This type of healing could be seen after external fixation. Some degree of instability might result in increased callus formation and some tolerable fragment end resorption as in the case of indirect healing. This type of healing also resulted in prompt and reliable bone union after external fixation. External fixation some time leads to excessive instability of the fragments, primarily by the application of a flexible device or secondarily by significant resorption of bone at the contact surface. This might delay or impede solid bone union.

Rochat and Payne (1993) opined that the age of the animals influenced the type of fracture repair. The fracture healed at different rates in animals of different age groups. It was faster in young animals compared to older animals.

Johnson and DeCamp (1999) had noticed that application of a weak fixator-bone construct caused an excessive deflection of the fixator resulting in movement at the
fracture site and pin-bone interface. Excessive movement at the fracture site could result in delayed union or non-union. However, use of external skeletal fixation in treatment of comminuted fracture resulted in satisfactory healing.

Langley-Hobbs (2003) opined that fractures of upper limb bones would heal faster than that of lower limb, because of a large surrounding soft tissue envelope.

Gemmill et al. (2004) observed that the mean time to clinical union (TCU) was 66 days for Type 1a frame, 49 days for Type 1a fixation with intramedullary pin (IMP), 56 days for Type 1b and 70 days for Type 1b.

2.4 External skeletal fixation (ESF)

2.4.1 Types of external skeletal fixators

Egger et al. (1985) evaluated Type I biplanar external skeletal fixation for the treatment of long bone fracture in dogs and cats and concluded that this configuration stabilized long bone fractures more effectively than Type II configurations.

Nunamaker (1985) described the use of full pin with connecting bars on either sides of the fracture and reported that it increased the strength of fixation by four fold than half pin fixation. Type II splintage triangulation increased the anterior / posterior bending rigidity.

Fox (1986) reported that the Kirschner apparatus was available in three sizes in small animal surgery. The medium sized device was more commonly used. The small
Kirschner apparatus was used in cats and dogs weighing less than 15 pounds, while large Kirschner apparatus was used infrequently, though effective in giant breeds.

VanEe and Geasling (1992) described the various configurations of external skeletal fixators as Type I, II and III. In Type I, the fixation pin passed through only one skin surface and two cortices of the bone. The connecting rods and clamps were thus positioned on only one side of the bone. In Type II, the fixation pins passes through two skin surfaces and two cortices of the bone, while connecting rods and clamps were positioning on both sides of the bone. Type III was a combination of Type I and II fixators with Type I fixator positioned at 90° to the Type II fixator giving the external frame a three dimensional shape.

Fox et al. (1995) opined that Type II external skeletal fixators were useful for surgical correction of antebrachial deformity in dogs.

Johnson et al. (1996) operated 23 dogs having severely comminuted mid-diaphyseal radial and tibial fractures by closed reduction and Type II external skeletal fixation. The authors concluded that closed reduction and Type II external skeletal fixator was an effective method of correcting severely comminuted radial and tibial fractures.

Harari et al. (1998) described the use of Type Ia frames to treat fractures above elbow or stifle joints, as bilateral configurations will injure the body wall. While, for fractures below elbow and stifle joints, Type Ib and Type II frames were used for procedures involving bone lengthening or arthrodesis. Type III frame was used for highly comminuted fractures with bone loss involving the radius and tibia. The small
Kirschner set could be used for dogs that weighed less than 12kg, medium set for dogs of 12 to 45 kg and large set for heavier animals.

Dee et al. (2000) reported external skeletal fixation as an important minimal invasive procedure in the management of fracture at the end of radius.

Marcellin (2003) opined that, the ESF frames could be linear, free form or circular. Linear frames had a single connecting bar (unilateral), two connecting bars (unilateral, biplanar or bilateral) or three connecting bars (bilateral biplanar). The circular external skeletal fixation frame consisted of rings connected by threaded rods; termed as Illizarov ring fixator. Linear and circular frames could be combined to form hybrid frames.

Gemmill et al. (2004) treated 62 cases of radial and tibial fractures with low stiffness Kirschner-Ehmer external skeletal fixation frames (Type 1a, Type 1a+IMP, Type 1b, Type 1b+IMP). The authors concluded that more rigid Type 2a or Type 3 frames were not necessary in the majority of cases and observed an increased morbidity compared with the use of more rigid frames. However, the authors opined that Type 1a frames were to be avoided in heavier patients.

Shahar and Shani (2004) compared the bilateral external skeletal fixator frames and unilateral external skeletal fixator which were combined with an intramedullary pin and the authors concluded that the unilateral external skeletal fixator combined with intramedullary pin as an equivalent stiffness module that was similar or even better than that of bilateral frames with a similar arrangement of transcortical pins.
Carlson *et al.* (2006) studied non linear stiffness profiles of external skeletal fixator constructed with composite rods. They concluded that composite connecting rods resulted in nonlinear increasing axial and bending stiffness in bilateral fixators and while axial load in unilateral fixators.

Clarke and Carmichael (2006) used hybrid external skeletal fixation for the distal diaphyseal fractures of radius in three dogs. They reported that, fracture healing was achieved in all cases. The constructs provide veterinary surgeon with another option in the management of distal diaphyseal / metaphyseal fractures.

Ness (2006) treated the inherently unstable open or infected fractures by open wound management with external skeletal fixation and reported that, external skeletal fixators were usually effective in maintaining stability throughout an inevitable extended fracture healing period.

Reaugh *et al.* (2007) evaluated the stiffness of modified configurations of Type 1a and with Type 1b external skeletal fixator frames by alternatively placing transfixation pins on opposite sides of the connecting rods (Type 1a MOD) or by placing additional connecting rods on either of the two inside (Type 1a - INSIDE) or two outside (Type 1a - OUTSIDE) transfixation pins. The authors concluded that Type 1b frame was stiffer than both Type 1a MOD and Type 1a.

Risselada *et al.* (2007) used Type II external skeletal fixator with a distal walking bar connected to the frame for stabilization of distal metacarpal or metatarsal bone
fractures in the dogs and reported that with this configuration, medio-lateral angulation had improved post-operatively in 10 out of 11 dogs.

Rovesti et al. (2007) reported that, circular external fixators represented an attractive surgical option to treat a variety of orthopaedic problems of antebrachium in dogs because of their stability and minimum invasiveness due to use of small diameter tension wires and their adjustability.

Pardeshi and Ranganath (2008) compared the Type 1a and Type 1b external skeletal fixation for tibial fracture repair in dogs and concluded that Type 1a double bar external skeletal fixation provided a better stability (caused less pain and promoted early weight bearing) as compared to Type 1b external skeletal fixation in dogs.

2.4.2 Advantages of External Skeletal Fixator

Burny et al. (1980) observed that, interfragmentary contact provided by half frame external fixation gave satisfactory stability in case of simple fractures. Early weight bearing ensured functional loading of bone and periosteal callus development.

Straw (1984) recommended the use of Kirschner-Ehmer (KE) splint to treat open fractures, infected fractures, comminuted fractures, gunshot fractures, non-unions, delayed unions, mandibular fractures, angular deformities and as an adjunct to internal fixation devices like pin, plate or cerclage wire.

Jenkins et al. (1987) reported that, colles fractures in humans could be treated either by a forearm plaster or by the application of an external skeletal fixator. The external skeletal fixation proved to be more effective in holding the manipulated position.
The radiological loss of position during fracture union was minimal compared to that of patients treated with plaster.

Pead and Carmichael (1989) stated that stabilization of fracture by external skeletal fixation can be accomplished with minimal surgical exposure, limiting the possible iatrogenic problems. They also reported that, this method was particularly suited for the management of severely comminuted fractures wherein it can be used to maintain bone length and alignment.

Denny (1991) reported the suitability of external skeletal fixation for open fractures with gross soft tissue damage, infected fractures or severely comminuted fractures. He opined that the pins were to be placed at some distance away from the fracture site to minimise the spread of infection.

VanEe and Geasling (1992) recommended external skeletal fixation to reduce the inventory requirements and cost.

Harari et al. (1998) reported the following advantages of external fixation which include a. ability to treat open and closed fractures, simple and comminuted fractures, gunshot fractures, angular deformities, joint luxations, shortened bone and delayed unions. b. Compatibility in using with an adjunct to intramedullary pin and cerclage. c. Ability to adjust fracture alignment and biomechanical properties of the fixators. d. Preservation of neurovascular supplies to bone and soft tissues. e. Technical ease of application and removal of the external fixators and f. Satisfactory mobilisation of limb and patient with minimal interference of adjacent joints.
Rochat (2001) observed external skeletal fixation to be minimally invasive besides allowing fracture haematomas and associated vascular supply to remain intact. He further stated that external skeletal fixation could be used as an adjunctive fixation device in association with intra medullary pin.

Ozsoy and Altunatmoz (2003) noticed early return of the limb to the function within 3-10 days and the patient was able to walk by touching the fractured leg onto the ground to a satisfactory extent within 20 days, thereby avoiding the possible complications like bone and muscle atrophy. External skeletal fixation with closed or limited open approach provided a very short healing period and sufficient stability. The ease of application and low cost of external skeletal fixators were also mentioned.

2.4.3 Disadvantages of External Skeletal Fixator (ESF)

Burny et al. (1980) reported that high shearing stress could not be avoided by simple half frame fixation in case of spiral or oblique fractures. They recommended delayed weight bearing (but active muscle function) and the addition of an internal screw to neutralise the shearing stress as a solution.

Okrasinski et al. (1991) reported several disadvantages of external skeletal fixation Viz., size of the clamp selected for fracture stabilization depended upon the selection of pin size and vice-versa. Further, the clamps and rods selected limited the angle and direction of pin placement. While, presence of appliance will obscure the radiographic evaluation of the fracture, the cost of implants will prohibit its usage.
Rochat and Payne (1993) observed that external fixation appliances might become entangled in objects and surrounding environment. Although external skeletal fixator could be used in any sized patient with any type of fracture configuration, it was often inadequate in very proximal and distal fractures.

Harasen (2003) reported that in case of femur, only lateral side has unobstructed access and the fixator pins must go through large muscle masses, which is associated with significant morbidity. Biologic fracture repair principles in case of femur do not apply well because of limitations in applying external skeletal fixator.

2.4.4 Components of linear external skeletal fixator

2.4.4.1 Fixation pins

Mathews et al. (1984) studied the thermal effects of external fixation pin insertion in human cadaveric cortical bone and observed that trocar and spade tipped pins producing very high temperature for long durations on drilling into the fracture fragments.

Nunamaker (1985) reported that, when diameter of pins increased (upto approximately 30 per cent of the bone diameter), the strength of the fixation is also increased by fourth power function.

Aron et al. (1986) compared smooth pins, threaded pins, and cancellous threaded and smooth pins in long bone fractures. They concluded that morbidity decreased significantly with the exclusive use of threaded pins or a combination of threaded and smooth pins when compared to the exclusive use of smooth pins. It also decreased the
occurrence of osteomyelitis and enabled effective staged removal of external skeletal fixator.

Many authors had recommended that the transfixation pin diameter should not exceed 20 to 25 per cent of the diameter of the bone (Egger, 1993; Gorse, 1998; Harari et al., 1998 and Gul and Yanik, 2006).

Palmer et al. (1992) opined that keeping the pin diameter smaller than 20 per cent of the bone diameter reduced the possibility of the bone fracture through a pin tract and increased rigidity for a given frame configuration.

Anderson et al. (1993) compared the use of unthreaded and threaded (positive and negative profile) pins in external skeletal fixator and found that normal functional limb usage was regained slowly in those animals in which non threaded pins were used. Further they felt that the positive profile pins had lower pin pullout force and lower bone holding power than negative profile pins.

Butterworth (1993) reported that the diameter of a pin should not exceed one-third of the diameter of the bone into which it was placed, in order to prevent stress related fractures.

Fox et al. (1995) attributed animals becoming lame as fixation pins became loose which was due to increased periosteal irritation besides loss of pin bone interface stability through pin loosening or breakage. They opined that, this would lead to poor limb usage, pain, loss of fracture reduction, delayed union or non-union and pin tract sepsis.
Johnson et al. (1996) opined that the type of pin (threaded or smooth) and number of pins had no significant effect on duration of surgery or development of callus or its removal.

Anderson et al. (1997) categorized external skeletal fixation pins as threaded and non-threaded pins. They used threaded pins more commonly as they not only improved the pin bone stability but also maintained stability for longer time.

Kraus et al. (1998) reported that the positive profile threaded pins were better than smooth pins as they reduced bone pin strain by increasing surface area between bone and fixator over which force can be transmitted.

Johnson and DeCamp (1999) found that, the pin tip configuration was the important aspect of pin design. Smooth pins were available with trocar, diamond or spade, half-drill whereas Hoffmann tips and threaded pins with trocar, blunt and drill-bit tips. Tip configuration has an effect on final pinhole diameter and bone temperature elevation during pin placement.

Marti and Roe (1999) compared the hallow ground with trocar pointed pins on threaded positive profile external skeletal fixator pins in canine cadaveric bone and reported that T tipped pins reached higher tip temperature in both diaphyseal and metaphyseal bone when compared to hallow ground tipped pins.

Pardeshi (2007) in his study, selected transfixation pins (half pins with end threaded and negative profile) having diameter of not more than 20 to 30 per cent bone shaft for the repair of tibial fractures in dogs.
2.4.4.2 Clamps

Boothe and Tangner (1983) used single fixation clamps in both full and half Kirschner apparatus and double fixation clamps in a full Kirschner apparatus.

VanEe and Geasling (1992) described two types of clamps, single and double. They found that, single clamps could be used to join transfixation pins to connecting bar whereas double clamps could not be considered as a universal joint connecting the frame of the fixator to be positioned in multiple planes.

Butterworth (1993) reported the use of polymethylmethacrylate (Technovit; Kulzer; Palacos.LV-30, Kirby-Warrick) or a proprietary car body filter to link the pins together as a less expensive alternative to stainless steel clamps and connecting rods.

Johnson and DeCamp (1999) described different types of clamps used in veterinary orthopaedics. They reported that, the secure-V external fixation clamps were available in small and medium sizes. SV clamps manufactured by IMEX Veterinary were available in small and large sizes.

Gilley et al. (2001) compared the mechanical stiffness of three external fixator clamps (Kirschner - Ehmer (K-E), Synthes and Meynard) and concluded that the K-E clamps were able to resist higher torsional and axial forces before loosening when compared to other clamps.

Lewis et al. (2001) compared Secur-U-clamp with Kirschner Ehmer clamps that deform upon tightening the tapered head component of the Secur-U clamp which was drawn into the centre of the V shaped component as the bolt is tightened thus providing a
more secure fixation to the connecting rod. The Secur-U clamp could be assembled and
disassembled and need not be preloaded on the connecting rod before application.

Julie et al. (2007) used an acrylic bar in radial fracture stabilization and they
found it to be a good choice to replace the stainless steel connecting bar and clamps as it
was light weight, cost effective and easy to apply.

2.4.4.3 Connecting bars

Harari et al. (1998) recommended the connecting bars of Kirschner apparatus of
different diameters like 1/8 inches, 3/6 inches and 7/16 inches for the small, medium and
large fixators respectively.

Johnson and DeCamp (1999) described two types of connecting bars to be used in
Veterinary orthopedics viz, K-E stainless steel connecting bar and SK connecting bar
made of carbon fiber, aluminum and titanium which were light weight and radiolucent.
They were available in different diameters like 4 mm, 6.3 mm and 9.5 mm.

Strok et al. (2003) compared the structural and mechanical properties of full
frame external skeletal fixator with rigid polymer connecting bar,
polymethylmethacrylate bar, stainless steel clamps and connecting bars. The authors
found that a structural and mechanical property of rigid polymer was satisfactorily rigid
and fatigue resistant. Further it was found to be reliable, versatile, nontoxic and
inexpensive option for the veterinary surgeon as reported.

Julie et al. (2007) suggested the use of acrylic connecting bar instead of stainless
steel for the fixation of transfixation pins for radius fracture correction.
2.5 Preoperative physical and clinical consideration.

Reichel (1956) suggested that, two radiographs should be taken and placed in front of the surgeon during the surgery to ensure the exact replacement of the fragments.

Gorse (1998) reported that “Hanging leg” position facilitated closed reductions by suspending the affected limb from the ceiling which helped to realign the fracture and also it allowed easy access to both sides of the limb.

Roush and McLaughlin (1998) advised to stabilize fractures temporarily before surgical correction in order to increase the patient comfort, to minimize the local soft tissue swelling and any further soft tissue injury.

Johnson and Hulse (2002) suggested that, while correcting any orthopedic defects a thorough physical examination of patient should be done before surgical intervention and definitive repair shall start only after attending to life threatening injuries, if there were any.

According to Langley-Hobbs (2003) two orthogonal radiographic views (i.e., taken at 90° to each other) including the joints proximal and distal to the fracture should be obtained before attempting fracture repair.

Corr (2005) suggested the hanging limb technique of positioning of the animal for the external skeletal fixator, which helped to re-align the fracture and stretch and fatigue the muscles.
2.6 Use of antibiotics in orthopedics

Dow (1988) opined that potassium penicillin G was a potent antibiotic against gram-positive aerobes and anaerobes, the most likely contaminants at the orthopedic surgical site.

Singh (1996) reported that Ampicillin, broad-spectrum semi-synthetic penicillin was the most commonly used antibiotic for orthopedic infection and it had been shown to had good bone and muscle penetration.

Harari et al. (1998) recommended administration of Cephalothin at the dose rate of 10 mg / lb orally thrice daily for 10 days in treatment of pin tract infection.

Johnson and Hulse (2002) recommended the usage of cefazolin 22mg / kg intravenously, intramuscularly or subcutaneously at six to eight hour interval as a prophylactic antibiotic for controlling orthopedic infections.

Perscott et al. (2002) reported that staphylococci showed 18 per cent resistance to first-generation Cephalosporins, although they were the commonly used antibiotic as the first line of defense against bone and joint infections.

Roush (2005) recommended one time administration of a first generation cephalosporin at a dose of 20 mg / kg body weight intravenously, followed by 20 mg / kg body weight administered intramuscularly to provide prophylactic antibiotic coverage for up to five hours in fractures patient for open orthopedic procedure.
Ness (2006) used clavulanate-potentiated amoxicillin in unstable septic tibial fractures treated with external skeletal fixators and found it to be effective in alleviating the infection and promoted early healing.

2.7 General Anaesthesia

Ramesh Kumar et al. (2004) reported that dogs were to be premedicated with Atropine sulphate at the dose rate of 0.04 mg / kg body weight subcutaneously and Triflupromazine hydrochloride at the dose rate of 1 mg / kg body weight intramuscularly, 10 minutes prior to the induction of general anesthesia using 2.5 per cent solution of Thiopentone sodium intravenously.

Julie (2005) in a study used Atropine sulphate (0.045 mg / kg body weight) and Xylazine HCl (1 mg / kg body weight) for premedication and intravenous administration of Xylazine-Ketamine (equal volumes) and Diazepam (0.25mg / kg body weight) for maintenance of anaesthesia in case of long bone fracture repair in dogs.

Singh et al. (2006) used Triflupromazine (1.0 mg / kg intramuscular) as preanaesthetic and 2.5 per cent Thiopental sodium as anesthetic for osteomedullography of radius in dogs.

Pardeshi and Ranganath (2008) reported that, the use of preanesthetic Xylazine HCl ( 0.5 mg / kg body weight) followed by 2.5 per cent Thiopentone sodium as general anesthetic resulted in good muscle relaxation in dogs undergoing tibial fracture repair.

Fazili et al. (2008) used Triflupromazine (1.0 mg / kg) intramuscular and Atropine sulphate (0.02 mg / kg) subcutaneously for premedication. Anesthesia was
induced and maintained with Thiopentone sodium (2.5% or 5%) intravenously for dogs undergoing long bone fracture repair.

2.8 Technique for application

2.8.1 Safe corridors for insertion of external skeletal fixator pins for the canine radius

Marti and Miller (1994) defined the only safe corridor present in canine fore limb, located on medial border of the radius. The proximal third of the medial border of the radius occupied by the pronator teres muscle and remainder of the medial border up to the medial styloid process of radius was palpable subcutaneously.

2.8.2 Principles and application of external skeletal fixation

Egger et al. (1985) reported that the most proximal and most distal pins were placed first after reduction of the fracture and at least two fixation pins in each fragment were to be placed at a divergent angle of approximately 40° to each other in order to maintain a mechanical grip on the bone.

Butterworth (1993) reported that the most appropriate location for Type I (unilateral uniplanar) fixator application in proximal radial fractures was lateral / cranial part of the bone and for distal radial fracture it was medial / cranial side of the bone. He proposed that, the pins should enter the bone at about 45 - 65° to the longitudinal axis after a stab incision on the skin for the prevention of pin loosening.

Corr (2005) described the broad guidelines for the selection of implants for the original K-E system which included, the use of small system for animals weighing less
than 5 kg, the medium system for animals weighing between 5 -30 kg and the large system for animals weighing above 30 kg. The author concluded that pin size should not exceed 25-30 per cent of the bone diameter.

2.8.3 Technique for application of linear external fixation for radius fracture.

Egger et al. (1985) described the techniques for application of Type I biplanar splint for radius fracture which included anesthetization of animals. Affected limb was prepared for surgical manipulation and fracture reduction was obtained either by closed external manipulation or open through a limited surgical approach. One fixation pin was placed on the proximal end of the proximal fragment and second fixation pin was placed in the distal end of the distal fragment to approximate longitudinal alignment. A connecting bar with the appropriate number of open connecting clamps was loosely attached to the end pins. The fracture was brought into final reduction and clamps were tightened. The middle fixation pins were driven through the remaining clamps and clamps were tightened. Similarly another half pin splint was applied and these two frames were bridged by addition of rods between proximal fixation pins and distal fixation pins of two longitudinal splints.

Carmichael (1991) listed following guidelines for successful application of fixators. They include, a) Selection of appropriate distal limb fractures, b) Good reduction of fracture (closed or open) before application of fixators, c) Use of unilateral configuration, if possible. d) Insertion of pins through individual small incisions, e) Placement of clamps 0.5 cm from the skin surface, f) Pre drill pin holes especially if
large pins were to be used, g) Insertion of pins at converging angles on each side of the fracture, h) Application of the apparatus to the tension side of the bone.

VanEe and Geasling (1992) reported that, it was preferable to use three or four pins per fragment and a minimum of two pins were required for each major fragment. They opined that, the fixation pins should be spread along the entire length of bone to get maximum advantage and the ideal method of pin insertion was to use a low speed, high torque power drill that allowed precise pin placement without much wobbling.

Butterworth (1993) described the technique for application of Type II external skeletal fixator which used full pins. The fixation pins were aligned in such a way that they can be attached to bars on both sides of the limb but, may lead to technical difficulties. The author concluded that, the frame could be modified so that only the most proximal and distal pins were full pins and later half pins were added from one or both sides. Type III fixators were made up of Type I and Type II fixators placed at right angles to one another. These were joined together proximally and distally with end on, in such a way that the appearance resembled a tent frame. The author also mentioned that this was the most rigid of basic configurations.

Clary and Roe (1996) observed that, the pre-drilling a pilot hole whose diameter approximated, but did not exceed the inner diameter of the positive profile pin would reduce the micro structural damage and premature pin loosening.

Harari et al. (1998) recommended that, pins should be inserted at a 60 to 70° angle to the long axis of the bone at least two cm away from the fracture site and a
minimum of two or three pins should be used for each large bone fragment. They applied external fixator by placing the pins in the most proximal and distal positions initially, then attaching sidebars with open clamps for the central pins. Before tightening the proximal and distal clamps, the fracture was reduced manually or with reduction forceps. After tightening the proximal and distal pin clamps, the central pins were inserted into the large bone fragments alternating pin insertion above and below the fracture.

Johnson and DeCamp (1999) proposed the use of a low-speed power drill (<150 rpm) or a hand chuck after pre-drilling of a pilot hole for the insertion of transfixation pins to the bone.

Corr (2005) described a procedure for linear ESF in dogs after an aseptic surgical preparation. The procedure included, a) Placing the most proximal and distal pins first, b) Attaching the connecting bar and preload appropriate number of clamps, c) Inserting the remaining pins through the clamps, d) Placing the pins not closer than three times their diameter to a fracture line or joint surface, and finally e) tightening the clamps.

Risselada et al. (2007) reported that in case of Type II external skeletal fixator the smooth pins were introduced under a 30° angle to the bone surface to prevent frame displacement due to pin loosening. Whereas, centrally threaded pins were placed perpendicular to the bone parallel to one another and to the joint surfaces after pre-drilling with smooth pin of the same diameter as the non-threaded part.
2.9 Post-operative care and management

Carmichael (1991) was of opinion that apparatus should be checked a day after surgery for limb swelling and interference by the patient. The author further suggested that, the discharge around the pins and rods should be cleaned daily besides covering clamps and pin ends with a protective bandage.

VanEe and Geasling (1992) recommended early ambulation following fracture fixation with external fixators, as weight bearing stimulated fracture healing and minimized fracture disease. The authors suggested to not to clean the dried serum or scab formed around the fixation, pin-skin interface and also suggested the routine inspection of the clamp for their fitness, which was important in preventing implant failure.

Butterworth (1993) reported that, the postoperative care of fixators was minimal. A light discharge from pin tracts was not uncommon and generally formed a crest, thereby sealing the pin/skin interface.

According to McLaughlin and Roush (1999), the patient’s activity should be restricted after fixator application to prevent breakage of transfixation pin and failure of fixator. The authors recommended leash walking to avoid joint stiffness.

Mathews (2000) suggested the use of Meloxicam at the dose rate of 2 mg/kg intravenously, subcutaneous once, followed by 0.2 mg/kg every 24 hrs for the treatment of moderate to severe pain.

Carneiro et al. (2001) evaluated the post-surgical treatment of per-cutaneous transfixation of the tibia in dogs and found that dogs treated with a 0.9 per cent sodium
chloride solution showed little purulent exudation, while dogs treated with 0.2 per cent iodine-alcohol presented dry skin wounds with minimum blood-serous to serous exudation. Predominance of Staphylococcus spp. was revealed through microbiological examination, but no differences were observed between the two treatments.

Anderson et al. (2002) suggested that, daily cleaning of the skin wire / pin interfaces post-operatively with cotton tipped applicators or sponges soaked in 0.05 per cent chlorhexidine diacetate until the fixators were removed besides placing the foam sponges between limb and the frame.

Canapp (2004) suggested that, post-operative gauge or sponges should be placed between the skin and connecting bar where as, sterile non-adherent gauge to be placed over any open wounds to prevent the cotton from becoming impacted in the wounds. The author opined that, the entire fixators and involved portion of limb might be wrapped to minimize the movement of the soft tissue adjacent to the pins and to protect the animal from impaling itself with the fixator.

Julie et al. (2007) used the Ceftriaxone sodium at the dose rate of 20 mg / kg body weight intravenously to prevent post-operative infection. They also advised the owner to restrict the movement of animal for two weeks after surgery and then allowing leash walk.

2.10 Clinical evaluation

Egger et al. (1985) described the clinical assessment of limb function which included, rating of the animal as excellent with continuous normal leg use whereas an
animal which use leg with occasional mild lameness as good, while animal with consistent severe or non-weight bearing lameness was rated as poor. They reported that, clinical examination revealed premature pin loosening and complications of external skeletal fixation.

Butterworth (1993) opined that the frame had to be checked on weekly basis to ensure that the clamps and / or pins were not loosened and to rule out the pin tract infection.

Fox et al. (1995) classified limb use after external skeletal fixator application as Excellent: functionally normal; Good: a slight lameness only after an extensive exercise; Fair: a slight to moderate lameness but consistent weight bearing; Poor: non weight bearing lameness.

Chaudhary (1997) observed a non significant variation in the serum calcium and phosphorus values in dogs during the fracture healing. It was also observed that, the serum alkaline phosphatase values increased till the 30th to 45th day during the healing of tibial fracture.

Piermattei and Flo (1997) concluded that, young animals showed faster clinical union of fractured bones following external fixation than the older animals.

Aithal et al. (1998) observed the elevated heart rate and respiratory rate post-operatively in dogs undergoing supracondylar femur fracture treatment.
Chandy (2000) reported that, the treatment of femur fractures with external skeletal fixators resulted in increased rectal temperature along with local warmth of the affected region of the limb. He opined that, the rise in temperature might be due to osteomyelitis.

Srinivasamurthy (2000) reported that, there was a rise in temperature, heart rate and respiratory rate up to third post-operative day in dogs treated for femur fracture. The author opined that, these changes might be due to reparative inflammatory process occurring at the fracture site of surgical wound.

Riaz (2004) found that, there was no statistically significant variation in the serum alkaline aminotransferase and aspartate aminotransferase levels in dogs surgically treated for vertebral fractures. The author also reported that, there was no variation in the enzyme levels. However, The author observed a significant increase in serum alkaline phosphatase levels till the end of the study period (six weeks) in dogs which underwent surgical correction for vertebral fracture by stabilization of vertebral column.

Julie (2005) reported that, there was no significant variation in the physiological parameters on using external skeletal fixation and opined that, incidence of fracture and the immobilization procedure employed did not produce any untoward systemic effects.

Chandy (2006) observed a non significant variation in serum calcium, phosphorus, ALT, AST and ALP values in dogs treated for vertebral fractures by stabilization of vertebral column.
Pardeshi (2007) reported in his study of external skeletal fixation for tibial fracture repair, there was a significant elevation of temperature, heart rate, pulse rate and respiratory rate between first and third post-operative days and subsequently returned to normal.

2.11 Assessment of pain in animals

Conzemius et al. (1997) concluded that, the physiological parameters including heart rate, respiratory rate, blood pressure and temperature were not consistent or reliable indicators of pain.

Firth and Haldane (1999) developed a scale (University of Melbourne Pain Scale) to evaluate the post-operative pain in dogs which covering physiological data and behavioral responses and concluded that the physiologic and behavioral responses were reliable to evaluate degree of pain in dogs during post-operative period.

Mathews (2000) categorized the pain into five different levels viz., severe to excruciating, moderate to severe, moderate, mild to moderate, mild and pain associated with external skeletal fixation as moderate pain (level) based on the pain, with an increased heart rate / respiratory rate / blood pressure.

2.12 Lameness grading

Aron et al. (1986) reported a five scale grading for functional limb usage as,

I: Non weight bearing
II: Weight bearing less frequent than non weight bearing
III: Weight bearing more frequent than non weight bearing
IV: Constant weight bearing with perceptible lameness.

V: No perceptible lameness

Anderson et al. (2002) reported five scale lameness grading system in dogs stabilized with external skeletal fixation which included,

Grade 0: normal limb function

Grade I: subtle, intermittent weight bearing lameness

Grade II: subtle, consistent weight bearing lameness

Grade III: obvious weight bearing lameness

Grade IV: intermittent non weight bearing lameness

Grade V: consistent non weight bearing lameness

2.13 Radiological evaluation

2.13.1 Plain radiography

Kantrowitz et al. (1988) in their study, after radiography of limb observed the pin tract osteomyelitis as a zone of radiolucency surrounding the pin with adjacent periosteal reaction.

Radiographic evidence observed by Johnson et al. (1989) on treatment of radial and tibial fractures using external skeletal fixation included presence of periosteal and endosteal callus formation and in some cases primary cortical union during healing process. All the bones had periosteal reaction around the transfixation pins. Radiographic signs of osteomyelitis were soft tissue swelling, aggressive periosteal reaction, cortical lysis and an increase in medullary density.
Binnington, (1990) reported that, in the initial stages of fracture healing, callus will be of fibrocartilaginous in nature with low mineral content, hence it was not visible on a radiograph.

Butterworth (1993) reported that, radiography was one of the tools to locate the fracture site before and after external skeletal fixation. The author also opined that, radiography of the fracture site should be repeated for four to eight weeks after surgery.

Ross and Matthiesen (1993) recommended immediate post-operative radiographs for examination of fracture reduction, placement of pin and joint alignment. They also opined that, appendicular injuries had to be radiographed every three to four weeks until the healing was complete.

Ness and Armstrong (1995) proposed the radiography of standard lateral and cranio caudal aspect of antebrechium to know the location and nature of fracture before going for ESF. They also observed that, in the radiographs taken after 3 months of fracture fixation with external skeletal fixation, healing was characterized by endosteal and modest periosteal callus formation with subsequent remodelling.

Johnson et al. (1996) reported that the mean time for bone union or bridging of comminuted fractures with callus was 11.4 weeks using external fixation. Type of bone healing observed radiographically was of endosteal and uniting callus formation. Periosteal callus formation was minimal.
Kraus et al. (1998) conducted a study on Type II fixation in 23 dogs for radial and tibial fracture and reported that, the time required for radiographic evidence of a bridging callus and removal of the fixators was 80 to 154 days.

Roush and McLaughlin (1998) noticed early signs of fracture healing at fourth week post-operatively viz., periosteal reaction around fracture, callus formation, minor resorption and remodeling of the fracture ends or primary bridging of a rigid stable fracture with woven bone.

Beck and Simpson (1999) reported that, radiographs of dogs taken post-operatively at sixth week which were stabilized with Type 1-2 hybrid external skeletal fixator for distal humeral fracture with tied in intramedullary pins, showed a significant bony callus formation at the fracture site.

Anderson et al. (2002) reported that, time required for radiographic union of antebrachial fractures in dogs which were stabilized with circular external skeletal fixator was between 42-105 days (mean ± SD, 57±20 days; median, 46 days).

According to Toal and Mitchell (2002), formation of intense periosteal callus could be due to stripping of periosteum at fracture site during injury or surgery.

May (2002) reported that, the variation in radiographic appearance of bacterial osteomyelitis depended on the stage of disease process. In acute cases, there was only a soft tissue swelling with no apparent osseous abnormality whereas, in chronic cases an extensive periosteal new bone proliferation, irregular pattern of bone lysis and sclerosis was observed. Focal lysis is often especially apparent adjacent to orthopedic implants.
Langley-Hobbs (2003) reported that, fixation or stabilization devices can be removed after getting the clinical and radiographic information on union. The author also reported that, radiographically, osteomyelitis look like irregular periosteal bone extending away from the fracture and soft tissue swelling might be present.

Julie (2005) noticed fracture gap was progressively filled up with callus from day seven to day 45 post-operatively in all the dogs.

Gul and Yanik (2006) observed periosteal callus formation from second week onwards post-operatively. They also reported clinical union in simple and closed fractures of tibia at 45th day, reduced with unilateral uniplanar external skeletal fixator but for the polytraumatized open fracture it was 65th day and for comminuted fractures it was 75th day and fixators were removed on these respective days.

Mahendra et al. (2006) in treatment of femur fracture observed slight periosteal callus on either side of fracture fragments with reduced fracture line on 30th post-operative day. The rigid fixation provided at the fracture site resulted in less callus formation. The 45th post-operative day radiographs revealed relatively denser periosteal callus indicating mineralization of the callus and fracture line delineate with bridging callus. They opined that remodeling of bone was influenced by the degree of rigidity.

Pardeshi (2007) suggested to take radiograph immediately after external skeletal fixation of fracture to evaluated proper reduction and alignment of fracture ends. The author also recorded that, on 0 day, there was no radiographic callus at the fracture site but progressively periosteal callus was noticed on 28 and 45 post-operative days and later bony union was noticed on 60th post-operative day.
2.13.2 Osteomedullography

Kaski (1971) described osteomedullography of tibia in man. The author recommended compression of soft tissue veins at the fracture site to enhance radiographic appearance of intraosseous veins. The author mentioned five major radiographic signs of venous flow through the radiological signs of the venous circulation across the fracture site as follows:

i. Intraosseous veins crossing the fracture site
ii. A sinusoidal network in the proximal fragment
iii. Periosteal veins in the proximal fragment
iv. The ascending branch of the main efferent vein
v. Veins passing along the periosteal callus

Alitalo et al. (1982) used urografin 60 per cent, about 2-9 ml as a contrast agent for the osteomedullography of long bones in canines and concluded that osteomedullography can be considered as a reliable clinical technique in evaluating the repair process of canine long bone fractures.

Chawla et al. (1982) infused 10 to 15 ml of either Meglumine iothalamate or Sodium iothalamate into the tibia of sheep with pressure and first radiograph was taken just before the completion of injection. They also reported that the clearance of contrast medium in both intraosseous and extraosseous venous networks were visible up to 2 minute post injection and at subsequent intervals viz., 4 and 6 min, only faint course of injected medium and the material was completely drained out from the medullary cavity as well as from extraosseous veins by 10 min post injection.
Chawla et al. (1983) reported that veins crossing the callus were not seen in any of the phlebograms, irrespective of the time intervals of observations and the technique used for fracture repair.

Khan (1996) reported that conventional osteomedullography did not provide adequate visualization of osseous circulation. The placement of a tourniquet proximal to the test bone helped to visualize the flow of the contrast medium through intraosseous as well as major soft tissue veins of the respective bone.

Fazili et al. (2006) reported that osteomedullography used (i) to demonstrate the normal venous circulation of bone, (ii) as an additional aid in the diagnosis of disease of bone as a result of alterations in its blood supply, (iii) to study the rate of disappearance of contrast material as an indication of the rate of blood flow through normal and diseased bone and (iv) to visualize the deep venous channels draining the bone. They conducted study of osteomedullography in delayed union and non-union fractures and reported that in normally healing fractures, the intraosseous flow of contrast medium crossing the fracture area was seen between 10 to 12 weeks after an injury at the latest and also reported the reason for no flow of contrast medium from one fragment to another in non-union cases which was due to pressure in the marrow which was so high that the intramedullary injection of the contrast medium was difficult. This was attributed to the fact that in fractures with non-union the marrow was closed with a bone plug at the site of the fracture.

Singh et al. (2006) reported that the medullograms were performed either by tourniquet or phlebocompression techniques. They reported the osteomedullography of
the radius by injecting about 4 to 6 ml of contrast agent (Sodium iothalamate 70% W/V) into the medial aspect of distal radius and latero-medial and medio-lateral views of osteomedullograms were made just at the completion of injection of contrast medium and also reported the venous system of the proximal metaphysoepiphyseal region was visualized much better than the distal one regardless of the site of injection of the contrast material and the technique used.

Umashankar et al. (2007) conducted the osteomedullographic study on tibial fracture healing in dogs. They injected 4 to 6 ml of contrast agent (iohexol) into the medullary cavity depending upon the size of the tibia. The results on 0 day osteomedullograph revealed accumulation of contrast media in the distal segment and leakage of the contrast media in the surrounding soft tissues at the level of fracture. On the day 7, pooling of the contrast media was seen in the distal segment. On day 14, radiograph showed contrast media restricted to distal segment of the tibia, since there was no reestablishment of blood vessels at the fracture site. On the day 30 osteomedullography showed the flow of the contrast media through the fracture site was uniform with no leakage, the reconstitution of the intraosseous venous circulation through the fracture site was evident. On day 45 radiograph, showed intraosseous veins crossing the fracture site and the ascending branch of main efferent vein in the proximal segment were seen.

Umashankar and Ranganath (2008) used nonionic contrast (Iohexol) agent at the dose rate of 100mg/kg body weight for the osteomedullographic study of tibial fracture healing in dogs.
2.14 Haematological evaluation

In order to provide attention to any lesions which may affect the outcome of the fracture in a patient, Whittick (1974) recommended a presurgical assessment of volume of packed red cells (VPRC), haemoglobin count and total white blood cells (WBC) count.

Benjamin (1998) reported that neutrophilia and lymphocytopenia might be seen as a response of the body to stress and inflammation.

Julie (2005) noticed no significant variation in white blood cell (WBC), erythrocyte sedimentation rate (ESR), neutrophil, lymphocyte, monocytes and eosinophil counts but found significant increase in haemoglobin by fourth post-operative week in dogs undergone radius and tibial fracture treatment using external skeletal fixator.

Pardeshi (2007) evaluated the physiological parameters in dogs and reported that, there was no significant variation in haemoglobin and total erythrocyte count. Monocyte, eosinophil and basophil counts were within the normal range but there was a significant neutrophilia, leuocytosis and lymhocytosis upto third post-operative day of fracture repair which could be due to inflammatory process originated at the fracture site.

Singh et al. (2008) conducted the study on correcting angular deformities after wedge osteotomy and stabilized with circular external skeletal fixator. The authors recorded in their study the haemoglobin (Hb), total protein, packed cell volume (PCV) and calcium did not show any significant variation from the base values and there was increase in phosphorous and alkaline phosphatase levels in the plasma.
2.15 Blood biochemistry

Singh et al. (1976) observed a non significant difference in the level of serum calcium and inorganic phosphorus during the healing period of experimental ulnar defects in dogs. But, there was significant increase in the serum alkaline phosphatase concentration at seventh and fourteenth post-operative days and returned to normal by sixth post-operative week.

Benoni et al. (1984) reported elevated levels of serum aspartate aminotransferase up to fourth post-operative day in human patients undergoing total hip arthroplasty and opined that elevation in value was due to skeletal muscle trauma.

Kumar et al. (1992) found that, there was a significant decline in plasma calcium and inorganic phosphorus during the healing period of 21 days in fractured dogs.

Chandy (2000) analysed the serum calcium, phosphorus and alkaline phosphatase level post-operatively and reported that, there was no variation in the serum calcium and phosphorus level. But, serum alkaline phosphatase level showed a significant increase from the pre-operative day to 28th post-operative day.

Julie (2005) observed significant decrease in the serum calcium levels by the fourth week post-operatively, which remained same during the sixth week. The author observed a significant decrease in the serum phosphorus levels during fourth and sixth week post-operatively. A significant increase in the alkaline phosphatase level by the second week and significant decrease by fourth week was observed in dogs with radial and tibial fractures treated with external skeletal fixators was observed.
Mahendra et al. (2007) reported no significant change in serum calcium and serum phosphorus levels post-operatively after treating femur fracture in dogs using intramedullary pinning and cerclage wiring. They observed significant increase in serum alkaline phosphatase levels throughout the study period, which might be due to the process of increased osteogenic activity and deposition of calcium salts at the site of fracture.

Pardeshi (2007) reported that, there was no significant variation in serum calcium and phosphorus level, but there was a significant increase in serum alkaline phosphatase and aspartate aminotransferase in dogs stabilized with external skeletal fixation for tibial fractures.

2.16 Complications during external skeletal fixation

Egger et al. (1985) reported that, the drainage from the fixation pin tracts was the most common complication which was resolved after pin removal.

Piermattei and Flo (1997) recorded pin loosening as the major complication in case of external skeletal fixator used for fracture repair.

Sequin et al. (1997) reported that complications from external skeletal fixation were common and the most frequent being pin loosening and pin tract infections. Other untoward sequelae of ESF included were delayed union, non union whereas fracture disease (atrophy of bone, soft tissue and cartilage) osteomyelitis, pin breakage, bone fracture and sequestration were rare. The authors opined that, excessive heat built up and
subsequent thermal necrosis following intracortical placement of a pin would weaken the bone making it more susceptible to fracture.

Complications observed by Ozsoy and Altunatmaz (2003) with external skeletal application were pin loosening, pin-base infection, nonunion, ankylosis and valgus deformation

Gemmill et al. (2004) reported that in cases where Type II b frames were used, pin loosening was more likely to affect full pins rather than half pins.

Corr (2005) reported that, the most of the complications seen with ESF were caused by poor technique which was unusually minor. These can be easily dealt with and rarely produce a negative outcome. The author observed some of the complications like premature loosening of the pins, pin breakage and pin tract infections.

2.17 Removal of the implants

Johnson et al. (1989) observed a median time of 10 weeks for fixator removal in 26 dogs with radial and tibial fractures. However, additional support after removal of skeletal fixator included a plaster of paris cast, metasplint and soft padded bandage.

Carmichael (1991) in his study, removed fixators by putting the animal under sedation or by physical restraint after confirming the fracture healing by radiography.

Staged disassembly of the component of the external skeletal fixator had been advocated by many authors to allow gradual loading of the healing bone (Aron et al.,

VanEe and Geasling (1992) in their study preferred sedation rather than general anaesthesia to remove the fixator device.

Butterworth (1993) suggested that, the fixator completely removed only when the healing is sufficient for the bone to bear weight without the need for bone splinting. If the healing progress well but not yet completed, then a process of staging down could be done.

Kraus et al. (1998) recorded that, the mean time for bridging callus and the removal of the fixators were 46 and 60 days respectively. They opined that, if a fixator wire was left longer, pin loosening could be more common.

Lauer et al. (2003) reported that, destabilization was a concept of pursuing gradual staged disassembly of external skeletal fixators intending to increase only axial loading of the fracture while controlling non axial loading.

Canapp (2004) reported that, destabilization as a mean of converting Type III fixators to a Type I configuration at sixth week; experimentally it had been shown to enhance fracture remodeling. They advocated the stage removal, when fracture healing was allowed which can be stimulated by gradually destabilizing the frame to allow increased load on the bone and to prevent stress protection.
Julie et al. (2007) reported that, the implants should be removed when there was a sufficient callus formation and when the animal could bear weight on the affected limb. The average time of implant removal was six weeks in all the animals stabilized with external skeletal fixator for long bone fracture repair.

Risselada et al. (2007) opined the removal of external skeletal fixator after radiographical healing of fracture which occurred at an average of 45 days post-operatively.