EXTERNAL SKELETAL FIXATION IN COMBINATION WITH INTRAMEDULLARY PINNING FOR MANAGEMENT OF LONG BONE FRACTURES IN DOGS

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Thesis submitted in partial fulfillment of the requirement for the degree of

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DECLARATION

I, hereby declare that this thesis entitled **'External Skeletal Fixation in Combination with Intramedullary Pinning for Management of Long Bone Fractures in Dogs'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **'External Skeletal Fixation in Combination with Intramedullary Pinning for Management of Long Bone Fractures in Dogs'** is a record of research work done independently by B.Venkateswaralu under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Dr.B.Venkateswaralu.**, a candidate for the degree of **Master of Veterinary Science in Veterinary Surgery and Radiology**, agree that the thesis entitled **'EXTERNAL SKELETAL FIXATION IN COMBINATION WITH INTRAMEDULLARY PINNING FOR MANAGEMENT OF LONG BONE FRACTURES IN DOGS'** may be submitted by **Dr.B.Venkateswaralu.**, in partial fulfillment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Among the long bones, femur and humerus are the two abaxially placed long bones held close to the body. Unlike other bones, immobilization of femur and humerus with external coaptation technique would often result in fracture instability and failure. Of all the long bones, highest incidences of fractures were seen in femur, followed by tibia/fibula, radius/ulna and humerus (Aithal et al, 1999).

Among the fracture immobilization the cheapest and simplest techniques was using external coaptation technique which has its application limited to simple fractures that are stable. Further, the femur and humerus that held close to the body are not amenable to this technique.

Fractures of femur and humerus are most commonly immobilized using intramedullary pinning technique. Although it resists the bending forces on all directions, it gave poor stabilization against shear forces of oblique, torsion forces of all fractures and axial compressive force of oblique and comminuted fractures.

The most effective and popular method of fracture fixation for long bones, especially femur and humerus, is plate osteosynthesis. Bone plates used for internal fixation are effective in countering tension and compression forces and not so effective to counter bending and torsion forces. Bone plates are usually preferred when postoperative comfort and early limb usage are desired. Major disadvantage with plate osteosynthesis is that it requires extensive exposure of fractured bone and requires removal of plates after adequate bone remodeling, owing to the lack of callus formation. Plate removal necessitates another major surgery on a later date. More over, bone plates and screws are very expensive and require extensive instrumentation.

External Skeletal Fixation (ESF) is a means of stabilizing fractures or joints using percutaneous fixation pins that penetrate both the cortices and are connected outside the body to form a rigid frame or scaffold. ESF is economical compared with bone plate fixation and multiple cast or splint applications. It is adjustable, lightweight, and it maintains limb length. It provides rigid stabilization and preservation of blood and nerve supply. Initial mechanical stabilization requirements of the fracture could be met with fixation devices and later on could be modified or destabilized to provide optimal stabilization throughout the healing period. The chief advantage is that the limb will return to a functional state earlier than with other forms of external coaptation with early ambulation, weight bearing etc. It is highly versatile because the apparatus is easy to apply and remove. Its clamps and connecting bars could be reused many times.

Among the different configurations of these external skeletal fixation system, Type I configuration was mostly preferred for immobilizing the fractures of femur and humerus. The close proximity of femur and humerus to the body wall makes unilateral pin splintage (Type I) most suitable and use of other configuration or frames are not practical due to the same reason. Another development in the use of external skeletal fixation is acrylic splints, made from dental grade non sterile polymethylmethacrylate, available from dental suppliers, which is a cheaper alternative to stainless steel external fixator. It could be easily contoured to the shape of the body and allows the greater freedom to place the pins from different planes.

Failure to withstand the shear forces in oblique fracture, torsion forces in all type of fractures and axial compressive force in oblique and comminuted fracture could be effectively resisted when intramedullary pinning was used in conjunction with external skeletal fixation. St-Jean *et al.* (1992) suggested the possibility of combining intramedullary pinning with external skeletal fixation along with other accessory fixation techniques like cerclage wiring for different types of fractures of long bones.

On scanning the available literature, reports from India were found to be scanty on the use of external skeletal fixation in combination with intramedullary pinning for the treatment of fractures of long bones. Hence, the present study is undertaken to evaluate the efficacy of external skeletal fixation in combination with intramedullary pinning for the management of fractures of long bones, especially femur in dogs.

Review of literature

2. REVIEW OF LITERATURE

2.1 INCIDENCE OF FRACTURE OF LONG BONES IN DOGS

2.1.1 Breed wise distribution

Balagopalan *et al.* (1995) in a survey of 208 cases, reported highest incidence of fracture of long bones among Alsatian (27.9%) followed by Doberman Pinscher (17.8%), Non Descript (17.3%) and Pomeranian (15.4%).

Aithal *et al.* (1999) reported highest incidence of fracture in non descript dogs, in a survey of 402 cases.

2.1.2 Age wise distribution

Singh *et al.* (1983) observed higher incidence of fractures among the age group of 0 to 1 year followed by 1 to 3 years, 3 to 6 years and then in above five years group.

The survey report of Balagopalan *et al.* (1995) revealed that the incidence of fracture in dogs was more in the age group of 3 to 6 months (30.8%), followed by 0 to 3 months (27.9%) .

Survey conducted by Aithal *et al.* (1999) revealed highest incidence of fracture (54%) among young animals aged less than one year followed by the age groups of 1 to 3 years (35.52%), 6 to 12 months age group (20.40%), 3 to 6 months (18.64%), less than three months (14.61%) and in above three years of age (10.83%).

2.1.3 Sex wise distribution

On reviewing fracture cases in canines, Singh *et al.* (1983) observed that males had higher incidence of fracture than females.

A survey comprising 208 fracture cases, conducted by Balagopalan *et al.* (1995) male dogs (63.16%) were more affected than females (36.84%) dogs.

Aithal *et al.* (1999) reported that incidence of male dogs affected (63%) were significantly higher than female dogs (37%)

2.1.4 Bone wise distribution

The survey conducted by Singh *et al.* (1983) revealed highest incidence of fracture among dogs in femur, followed by tibia, radius and ulna, and humerus.

Nunamaker (1985) found that commonly encountered fracture in veterinary practice were in humerus and femur.

Balagopalan *et al.* (1995), reported higher incidence of fractures of long bones in femur, followed by tibia and fibula, radius and ulna, and humerus.

Aithal *et al.* (1999) found that among long bones, the incidence of fracture was highest in femur, followed by tibia and fibula, radius and ulna, and humerus.

2.2 FRACTURE BIOLOGY AND BIOMECHANICS

Bone as a structure might be loaded with tension, compression, bending, shear, torsion, or a combination of these forces. If the magnitude of the applied load slightly exceeds beyond the elastic limit, catastrophic failure might takes place. (Nunamaker 1985).

Bending causes a transverse fracture on the tension side and slight oblique fracture on the compression side of the bone. Axial compression causes an oblique fracture. Combination of axial compression and bending cause oblique comminuted fracture. Torsion causes a spiral fracture. High energy force causes a comminuted, nonreducible fracture. (Johnson and Hulse, 2002)

Bones fractured when extrinsic or intrinsic forces were applied and both elastic (reversible) and plastic (irreversible) deformation occur before breakage. In an oblique fracture, shear and compressive forces predominated. In transverse fracture, rotational or torsion forces predominated (Hulse and Hyman, 2003).

2.3 FRACTURE HEALING MECHANISM

As noticed by Heim *et al.* (1992), axial compression in a simple transverse fracture by means of a 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 a medullary nail. A fracture, which was rigidly stabilized, showed direct healing, characterized by minimal callus formation, without any resorption at the ends of the fragments and direct 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 allowing excessive instability of the fragments, whether primarily by application of too flexible a device or secondarily by significant resorption of bone at the contact surface, might delay or impede solid bone union. Soft tissue conditions after trauma and the start of weight bearing influenced the time of fracture healing.

Rochat and Payne (1993) opined that the age of the patients influences the type of fracture repair adopted as the fracture heals at different rates in animals of different ages. Fractures heal faster in young animals and slow in older animals.

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

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

Gemmill *et al.* (2004) observed that the mean time to clinical union (TCU) was 66 days for Type IA frame, 49 days for Type IA fixation with IMP, 56 days for Type IB fixation with IMP and 70 days for Type IB.

2.4 TYPES OF EXTERNAL SKELETAL FIXATORS

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

VanEe and Geasling (1992) described the various frame configurations of external fixators and they are,

Type I: The fixation pin passing 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.

Type II: The fixation pins passes through two skin surfaces and two cortices of the bone. Thus the connecting rods and clamps were positioned on both sides of the bone.

Type III: This was a combination of the Type I and Type II fixators, with the Type I fixator positioned at 90 degrees to the Type II fixator, giving the external frame a three dimensional shape.

Harari *et al.* (1998) described the use of Type IA frames used to treat fractures above elbow or stifle joints, as bilateral configurations will injure the body wall. For fractures below elbow and stifle joints, Type IB and Type II frames were used and 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.

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

2.5 COMPONENTS OF LINEAR EXTERNAL FIXATORS

2.5.1 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 produced very high temperature for long durations on drilling into the fracture fragments.

Nunamaker (1985) demonstrated that, as the pin diameter increased (upto approximately 30% of bone diameter), the strength of fixation increased by fourth power function.

VanEe and Geasling (1992) observed the Ellis fixation pins with a short, threaded portion to engage the transcortex and a smooth portion for the ciscortex, reduced the risk of breakage and its threads increased the pull out resistance.

Anderson *et al.* (1993) compared the use of nonthreaded and threaded (positive and negative profile) pins used in external fixator and found that the normal functional limb usage was regained only slowly in those animals where nonthreaded pins were used. The positive profile pins had lower pin pullout force and lower bone holding power than negative profile pins.

Johnson *et al.* (1996) proved that the type of pin (threaded or smooth) and number of pins did not have a significant effect on surgery time, time for development of bridging callus or time for fixator removal.

Anderson *et al.* (1997) categorised external skeletal fixation pins as threaded and nonthreaded pins. Threaded pins were more commonly used because they improved the pin-bone interface stability immediately after surgery and maintained this stability longer. The commonly used veterinary external skeletal fixation pins were smooth Steinmann pins, completely threaded Steinmann pins, partially threaded Steinmann pins and Ellis pins (end threaded negative profile pins). Increasing pin diameter increased the pin stiffness, decreased the strain at pin-bone interface and increased the pin-bone contact area. However, excessive pin diameter weakened the strength of the bone. So they recommended pin diameter range of 20% to 30% of the bone diameter at the site of implantation.

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

2.5.2 Clamps, connecting bars and wrench

Egger (1983) observed that the weakest component of the single connecting bar configuration was the connecting bar, especially at the fracture gap.

According to VanEe and Geasling (1992) clamps come in two types; single and double. Single clamps joined transfixation pins to connecting bar. Double clamps could be considered as a universal joint, connecting the frame of the fixator to be positioned in multiple planes. Connecting bars were special rods or Steinman's pins used to unite the fixation pins to provide a rigid frame outside the body.

Harari *et al.* (1998) opined that the pin clamps had fixation pins of various sizes but required a specific connecting bar. Double clamps provided more versatility in attachment to two sidebars, but size, expense and frame stability limited their use. To tighten the pin clamps, an open ended bar or socket wrench was required.

2.6 ADVANTAGES AND DISADVANTAGES OF EXTERNAL SKELETAL FIXATORS

2.6.1 Advantages

Burny *et al.* (1980) noticed 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 Krischner Ehmer (KE) splint to treat open, infected, comminuted fractures, gun shot fractures, nonunions, delayed unions, mandibular fractures, to correct angular deformities and as adjunct to fixation devices like pin, plate or cerclage.

Fox (1986) found that Kirschner external fixation was economical and requires no hardware to be placed directly on the fracture site when compared with bone plate fixation and multiple cast or splint applications.

VanEe and Geasling (1992) recommended the reusage of clamps and connecting rods, which will reduce inventory requirements and lower costs.

According to Harari *et al.* (1998) the advantages of external skeletal fixation included the following features; it has the ability to treat open and closed fractures, simple and comminuted fractures, gun shot fractures, angular deformitis, joint luxations, shortened bones and delayed unions. Its compatibility with internal fixation devices such as intramedullary pins and cerclage, ability to adjust fracture alignment and biomechanical properties of the fixator. Fracture stability could be maintained during healing and bone loading could be performed four to six weeks after repair during fracture remodelling by reducing the number of pins or sidebars. It provides accessibility for soft and osseous tissue wound management and is very economical where the components such as pin clamps and sidebars could be reused. There is an absence of stabilization devices within contaminated wounds and no need for soft tissue coverage of implants. It provides preservation of neurovascular supplies to bone and soft tissues. Its application and removal of external fixator is technically easy and there is satisfactory mobilization of limb and patient with minimal interference of adjacent joints.

Rochat (2001) observed ESF to be minimally invasive that allowed fracture haematomas and the associated vascular supply to remain intact. For treating fractures of humerus and femur where no safe corridor exists, ESF could be used as an adjunctive fixation device in association with an intramedullary pin.

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

2.6.2 Disadvantages

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

Boothe and Tangner (1983) found that Type I Kirschner apparatus in dogs with comminuted femoral fracture has not been routinely successful.

Egger (1983) demonstrated experimentally that Type IA unilateral configuration to be a relatively weak configuration, although it can be easily applied to the lateral surface of the humerus or femur.

Okrasinski *et al.* (1991) observed the following disadvantages of ESF that size of the clamp selected for fracture stabilization depends upon the selection of pin size and vice-versa. In addition, the clamps and rod selected will limit the angle and direction of pin placement. Further presence of appliance will obscure radiographic evaluation of the fracture and finally the cost of implants will prohibit its usage.

Rochat and Payne (1993) found that external skeletal fixation appliances may become entangled in objects of surrounding environment. Although ESF could be used nearly in any size patient with any type of configuration, it is often inadequate in very proximal or distal fractures.

Harasen (2002) opined that in case of large breeds a biologic approach to fractures of humerus or femur required some modification and ESF alone is seldom applicable.

Harasen (2003) reported that in the 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.

2.7 ALTERNATIVES FOR STAINLESS STEEL EXTERNAL FRAME

According to Tomlinson and Constantinescu (1991), three types of acrylic could be used as alternative to the stainless steel connecting bar;

- A hoof repair material - Technovit (Jorgensen laboratories)
- Dental grade nonsterile methylmethacrylate which was inexpensive.
- Out dated or opened surgical grade methylmethacrylate, which could be obtained from local hospitals. In date surgical grade methylmethacrylate would be costly.

Roe and Keo (1997) recommended epoxy putty as a suitable material for free form external fixators because they were easy to handle, inexpensive and had suitable setting times and mechanical properties.

A modified acrylic fixator was used by McCartney (1998) in which acrylic was used only at the junction between the pin and stainless steel bar and found that it gave results similar to those obtained with Kirschner external fixator.

Rochat (2001) mentioned that the economic advantage of acrylics, light weight titanium and carbon fibre connector rods are ore often overweighed by their functional advantage because they are reasonably priced, readily available and uniplanar, unilateral frames allow multiple insertion angles.

Johnson and Hulse (2002) described free form fixation as a form of external skeletal fixation in which the pins were interconnected with a polymer. This was performed with polymethylmethacrylate columns as connecting bars. The availability of commercial kits for Acrylic –Pin External Fixation (APEF) was also reported.

2.8 ACRYLIC CONNECTING BARS

Okrasinski *et al.* (1991found a 2-cm unilateral acrylic ESF to be superior to medium Kirschner ESF in compression and shear loads. Acrylic ESF performed as par with Kirschner ESF in torsion loads.

Tomlinson and Constantinescu (1991) developed acrylic ESF to treat fractures that are not amenable to Kirschner-Ehmer apparatus. It is highly indicated in small dogs, cats and birds.

Polymethylmethacrylate is a polymer with chemical formula – $[CH_2C (CH_3) ((CO) OCH3)-]_{n,}$ commonly used as bone cement or as an implant housing material. It was the same material as Plexiglas or Lucite. It was supplied as a liquid and a powder. The liquid consisted of unpolymerised monomer (methylmethacrylate), a small amount of hydroquinone (to extend shelf life by preventing premature polymerisation of liquid) and a curing agent N, N-dimethyl-p-toluidine. The powder was composed of various sizes of small beads of polymethylmethacrylate and a copolymer such as ethyl methacrylate-styrene. The powder was mixed with liquid (40g of powder in 20ml of liquid). The copolymer in powder helped the monomer liquid to wet the solid beads, allowing the whole mass of liquid and solid to polymerise completely and form a solid. A relatively small quantity of barium sulfate could also be added to the powder to allow the subsequent x-ray characterization. The reaction gave off heat, capable of killing tissues in the immediate vicinity of the bone cement. Polymethylmethacrylate was created by a polymerisation reaction between liquid and powder monomers in which individual monomer constituents were linked together to form high molecular weight molecules (Greer and Pearson, 1993).

Ross and Matthiesen (1993) demonstrated the preparation of acrylic connecting bar to a doughy consistency by mixing liquid and solid monomers and rolled it by hand into a cylinder and placed it over exposed pin ends allowing 1.0 to 2.5 cm between the skin and connecting bar. Generally the connecting bars are prepared of a diameter of 2 to 2.5 times that of the bone.

Martinez *et al.* (1997) mentioned the preparation of acrylic connecting bar by pouring the methylmethacrylate into plastic tubes. They recommended the use of saline soaked sponges between the patient and acrylic column and by placement of the column 10 mm away from the body surface prevents potential thermal injury to the soft tissues and bones.

Solid methylmethacrylate was prepared by mixing a volatile liquid monomer solvent with methylmethacrylate powder. The initial liquid stage, which lasted for two to three minutes, was followed by a doughy, mouldable phase (four to five minutes) that hardened into a very strong mass by seven to ten minutes after initial mixing. The recommended proportion of mixing of acrylic was three parts powder of dental acrylic to one part liquid stage application of acrylic (Piermattei and Flo, 1997)

Shahar (2000) recommended 9.53 mm or 15.9 mm diameter acrylic column for small or medium external fixator system and even a 31.75 mm diameter acrylic column for giant breeds.

2.8.1 Advantages of acrylic connecting bars

Okrasinski *et al.* (1991) demonstrated that acrylic column allowed freedom of pin placement by the surgeon. In addition being radiolucent does not impede the radiographic evaluation of the underlying bone. And the approximate cost of a Type 1 acrylic ESF that uses six 3.2 mm fixation pins is 75% less than equivalent Kirschner ESF.

Ross and Matthiesen (1993) demonstrated the use of multiple pins and methylmethacrylate ESF in dogs and they observed that without the limitation of pin diameter, spacing or spatial alignment, the acrylic connecting bars allowed the use of multiple pins in different planes.

According to Williams *et al.* (1997) acrylic connecting bar provided the advantage of application ease, economical use and flexibility in placement of fixation pins. Also pins of varying diameter could be used in the column.

McLaughlin and Roush (1999) observed that acrylic connecting bars were lighter, less bulky and could be customized for any size and shape of the bone. The fixation pins need not be perfectly aligned to be properly attached to an external acrylic connecting bar.

Advantage of acrylic connecting bar, as noticed by Chandy (2000) was it provided a cheaper alternative to stainless steel external fixator as it did not require the expensive components as used in the latter. Acrylic fixator also provided proper external stabilization.

According to Shahar (2000) acrylic column could be contoured to the shape of the body and permits easier application of transcortical pins in different planes. He found that acrylic connecting bar was economical, simple to apply and adaptable to a wide variety of pin diameters when compared with the standard stainless steel system.

Acrylic external fixator was used by Cook *et al.* (2001) for rostral mandibular fractures in dogs and found that polymethylmethacrylate connecting bar was advantageous in the clinical setting because of its low cost, ease of application and adaptability for use with curvature of bones.

2.8.2 Disadvantages of acrylic connecting bars

Some drawbacks encountered by Okrasinski *et al.* (1991) during preparation of acrylic were the release of large volume of noxious fumes, necessitating its usage in a well ventilated area. In addition, methylmethacrylate undergoes high exothermic reaction during its hardening which causes potential thermal injury to the skin surface. Poor pin-acrylic interface will occur if acrylic prepared is too stiff to fill the mold adequately.

Tomlinson and Constantinescu (1991) found that there lies no advantage of using acrylic external fixation instead of Kirschner-Ehmer apparatus in dogs that weigh more than 10 kilograms.

VanEe and Geasling (1992) revealed that once polymerisation occurred on using acrylic connecting bar, pin adjustment was not possible.

Ross and Matthiesen (1993) mentioned that postoperative adjustment and difficulty in removing the loose or infected pins were the major disadvantage of acrylic connecting column. Problems like skin irritation and infection could be encountered at skin- pin interface if the acrylic connecting bar was placed too close to the skin surface. Failure or breakage of acrylic connecting bar was noticed due to insufficient use of methylmethacrylate.

Martinez *et al.* (1997) demonstrated that TECHNOVIT and APEFS acrylic connecting bars cause potential thermal injury to soft and bony tissue, when the transfixation pins or Kirschners wires were positioned 5 mm from the patient's body surface.

Shahar (2000) reported technical difficulty in using large acrylic column in giant breeds. This led to the risk of nonhomogeneous acrylic formation, caused by entrapment of air during polymerization process of acrylic.

2.9 INTRAMEDULLARY PINNING

Fanton *et al.* (1983) observed that the more insidious sequelae following intramedullary pinning in femur was the injury to the sciatic nerve, because it passes through the gluteal muscles medial to the trochanter major and continues caudal to the coxofemoral joint.

McPherron *et al.* (1992) found those intramedullary pins when placed within the medullary cavity near the neutral axis of the bone are highly resistant to plastic deformation and failure.

St-jean *et al.* (1992) reported the neutralization of all major forces acting on the long-bones fractures when external skeletal fixation was combined with intramedullary pin.

According to Langley-Hobbs *et al.* (1996), intramedullary pin provide good stabilization only against angular deformity of femoral fractures, which are subjected to torsional, shear, compression and bending forces.

Lorinson *et al.* (1997) opined deep placement of intramedullary pin into the distal femoral epiphysis (DFE) for the successful outcome. To estimate safe pin penetration into the DFE using retrograde or normograde technique, patella thickness could be used. With normograde fashion, intramedullary pin could be safely driven into the DFE a depth equal to 30% of patella thickness.

Anderson and Aron (1998) made study on repair of humoral and femoral fractures with external skeletal fixation and recommended that the intramedullary pin selected should not be more than half the diameter of the isthmus of the bone.

2.9.1 External skeletal fixation with intramedullary pinning

Aron and Dewey (1992) and Matthiesen (1992) opined that combined use of ESF and intramedullary pinning provided stability against shear, torsional and bending forces, as well as axial compressive forces.

Ability of the external skeletal fixator to control bending could be significantly improved by combining with intramedullary pin and found that the values for parameters such as load to failure, load to yield, safe load, and stiffness under compression were significantly greater for the ESF-intramedullary pin combination with four pins compared with two pins (Mcpherron *et al.* 1992).

For effective immobilization of femur, VanEe and Geasling (1992) recommended the combination of Type IA external skeletal fixation with intramedullary pins and cerclage wires. Pins were drilled as far proximal and distal, as possible to avoid heavily muscled areas.

Marti and Miller (1994b) reported that treatment of fracture of humerus with external fixation alone or in combination with intramedullary pinning system was technically easier and considerably less expensive than plating.

Langley-Hobbs *et al.* (1997) indicated ESF in combination with intramedullary pinning for mildly comminuted fracture, where fracture reconstruction was possible and recommended two-pin fixator when ESF was used as an antirotational and anti compression device in combination with intramedullary pin. The intramedullary pin selected should be of larger diameter that it nearly filled the intramedullary canal.

Anderson and Aron (1998) reported that internal fixation such as intramedullary pins and wires should be used only to augment ESF and not vice-versa. They found that the ESF with intramedullary pin combination effectively stabilized a humoral or femoral fracture.

Radke *et al.* (2006) recommended the combination of a unilateral (Type I) external skeletal fixator (ESF) with an intramedullary pin (IM-pin) for treatment of femoral and humoral fractures in dogs and cats and found that the addition of intramedullary pin enhances the unilateral constructs in clinical cases.

2.9.2 Tie- in configuration of ESF with intramedullary pin

Aron *et al.* (1991) reported that tie-in configuration further increases the bending resistance of intramedullary pin-external fixator construct. This allowed the surgeon to construct more rigid frames and successful in immobilizing the fractures of femur and humerus, where only unilateral frames are used.

Dewey *et al.* (1994) reported high rate of complications, including delayed union and quadriceps contracture or tie down, with the combined use of a Type IA unilateral fixator and an intramedullary pin in femoral fracture repair.

Anderson and Aron (1998) noticed that for short-oblique and transverse fractures of femur and humerus, the ideal method was tie-in configuration of ESF with intramedullary pin and suggested that the diameter of the intramedullary pin should not be more than 50 percent of the diameter of the bone.

Radke *et al.* (2006) recommended the use of "tied-in" intramedullary pin with the ESF to provide high rigidity for a successful fracture repair.

2.10 PREOPERATIVE CONSIDERATIONS

2.10.1 Clinical evaluation of fracture case

Johnson and Hulse (2002) stated that to correct orthopaedic defects no surgical intervention should be conducted before thorough physical examination of the cases. Definitive repair should start only after attending life threatening injuries, if present.

2.10.2 Radiographic evaluation of fracture case

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

2.10.3 Preoperative preparation

Reichel (1956) recommended that two radiographs should be taken and placed in front of the surgeon during performance of surgery for the exact replacement of the fragments.

Gorse (1998) reported "Hanging leg" position facilitated closed reductions. Suspending the affected limb from the ceiling helped to realign the fracture and allowed easy access to both sides of the limb.

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

2.10.4 Anaesthesia

For the repair of fracture in dogs Julie (2005) reported the usage of atropine sulphate (0.045 mg/ kg body weight) and xylazine hydrochloride (1 mg/ kg body weight) intramuscularly for premedication and intravenous administration of xylazine-ketamine (equal volumes) and diazepam (0.25mg/kg body weight) for maintenance of anaesthesia.

2.11 SURGICAL APPROACH TO LONG BONES

In case of femur and humerus, Carmichael (1991) recommended the insertion of fixation pins in the lateral and craniolateral positions respectively.

Butterworth (1993) revealed that humerus and femur have no real safe corridors as they are surrounded by muscles and recommended a guideline for most appropriate location for a Type I (unilateral, uniplanar) fixator for various long bones. Both humerus and femur were approached through lateral aspect, where as the approach for proximal radius is cranio-lateral and that for distal radius is cranio-medial. Tibia is approached medially.

Piermattei (1993) mentioned a standard approach via craniolateral incision for open reduction and internal fixation of humerus between the triceps and brachialis muscle.

Safe corridors were defined by Marti and Miller (1994a) as longitudinal regions through which pins could be safely inserted, as they contained neither musculotendinous units nor important neurovascular structures. They conducted anatomical dissection of fresh canine specimens and carried out cross sections to identify the location of safe corridors for external skeletal fixator pin insertion. No safe corridor for pin insertion could be identified in canine femoral region. So pin insertion was to be limited to the lateral aspect of femur. Their study showed that in the canine tibia, the entire medial aspect and part of the cranial aspect represented a safe corridor for external fixator pin insertion.

Marti and Miller (1994b) found humerus as a concentric bone with no safe corridor. However, a safe area existed in the craniolateral aspect of the proximal humerus, which gradually tapered to a line distally.

Johnson *et al.* (1996) suggested the landmark for insertion of most proximal and distal pin in tibia. They found that the sites were located along the medial surface of proximal tibia and medial or lateral epicondyle respectively.

Gorse (1998) mentioned the placement of transfixation pins medial to lateral side with the frame on the medial aspect of tibia.

Johnson and DeCamp (1999) opined that the placement of pins should be in the healthy tissues in between the muscle bellies and should avoid major neurovascular structures.

2.12 PRINCIPLES AND APPLICATION OF LINEAR EXTERNAL SKELETAL FIXATORS

2.12.1 Principles

Boothe and Tangner (1983) recommended some principles to enable successful use of the full and half Kirschner apparatus so as to achieve maximum stability. The Kirschner pins should be inserted as near the ends of the bones, avoiding crossing of open physis inorder to avoid serious growth disturbances. Hand chuck should be preferred when compared to fast drilling power equipment which may predispose to earlier pin loosening caused by thermal necrosis of bone and each transfixation pin should be inserted at an angle of 65 degrees to the bone and each pins in the proximal and distal fragment should form an angle of 45 degrees with each other. Maximal fracture stability could be achieved by anchoring the pins on to both the cortices which helps to avoid premature pin loosening. Further, they suggested insertion of each pin through a separate skin incision, application of Kirschner apparatus to the tension side of the bone, placement of single fixation clamps on the pins approximately 0.5 cm above the skin surface and placement of long connecting bar approximately 1 cm above the skin surface.

2.12.2 Application technique

Straw (1984) inserted the percutaneous pins at an angle of 45 to 60 degrees to the longitudinal axis of the bone to avert the possibility of pin loosening if the angle was too perpendicular to the long axis. The proximal and distal pins were placed relatively near the ends of bone to resist the bending and torsional forces on the bone.

According to Nunamaker (1985) the most proximal and distal pins were positioned as far away from the fracture site as possible and the middle pins as close as possible close to the site. It was also recommended that the percutaneous pins in each fragment should be placed at an angle of 35 to 40 degrees or greater in relation to each other to prevent the pins from pulling straight out of the bone. Larger the diameter of the pin (up to approximately 30 percent of the diameter of the bone) stronger would be the fixation. As distance of connecting bar from bone increased, the rigidity of fixation decreased by third power function.

To neutralize the distractive forces, Fox (1986) suggested application of Kirschner apparatus to the tension side of the bone: application of splint to the lateral side on the humerus, femur and ulna, to the medial side in the case of tibia and medial or craniomedial side in case of radius.

McPherron *et al.* (1992) immobilized femur by applying Type I ESF to the lateral aspect with the transfixation pins driven at an angle of 70 degrees to the long axis of the bone.

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

According to Butterworth (1993) the diameter of the pin as a general rule should not exceed one-third of the diameter of the bone into which it is placed and suggested a fixation pin diameter of 1/16" to 3/32" (< 7kg), 3/32" to 1/8" (7 to 20 kg) and 5/23" to 3/16" (20 to 50 kg). In addition, he recommended the connecting bar diameter of 1/8" (< 7kg), 3/16" (7 to 20 kg) and 5/16" (20 to 50 kg).

Clary and Roe (1996) observed predrilling a pilot hole whose diameter approximates, but does not exceed the inner diameter of the positive profile pin would reduce the microstructural damage and premature pin loosening.

Anderson *et al.* (1997) described that there was no risk in pin insertion on the lateral surface of femur, because all the neurovascular structure were medial and caudal to the femur. They mentioned that the craniodistal half of the femur is avoided so as not to penetrate large muscle group. Because of excessive soft tissue movement around the pin, they noticed increased inflammation and premature pin loosening when transfixation pins were placed in the distal femur near the stifle.

The fundamentals of application of external skeletal fixator were suggested by Piermattei and Flo (1997). They included,

1. Use of aseptic technique
2. Proper bone surface location for insertion of pins

3. Use of the most suitable configuration of the splint
4. Use of auxiliary fixation when indicated
5. Reduction of fracture and maintenance in reduction during application of splint
6. Insertion of pins through soft tissue in a manner that does not distort the tissue
7. Proper pin drilling technique
8. Insertion of pins through both cortices of bone
9. Insertion of all related fixation pin clusters in the same plane
10. Insertion of pins in the proper location of bone fragment
11. Insertion of two or four pins in each major bone fragment
12. Choose optimal size fixation pins and connecting bar
13. Place the connecting rods at optimal distance between fixation clamps and skin
14. Significant cortical defects should be filled with bone grafts.

Harari *et al.* (1998) recommended that, pins should be inserted at a 60 to 70 degree angle to the long axis of the bone, at least two centimetre away from the fracture site. At least 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.

The current recommendation for the insertion of transfixation pins is to use a low-speed power drill (<150 rpm), or a hand chuck after predrilling of a pilot hole (Johnson and DeCamp, 1999).

The guidelines followed by McLaughlin and Roush (1999) were to make small longitudinal stab incisions on the skin over the insertion site and then to insert pins by using low speed power insertion (about 150rpm) with a power drill, avoiding vessels, nerves and large muscles. To maximize fixator stiffness, the number of pins in each fragment had to be increased (three or four pins were ideal).

According to Rochat (2001) pins selected for transfixation should be about 20% of the diameter of the bone at the intended site of pin placement. The pins were inserted parallel to each other and distributed from about one centimetre from the fracture site and one centimetre from the adjacent joints. After making a stab incision, the soft tissues should be bluntly separated and a drill sleeve should be inserted to protect the soft tissues. An appropriate drill bit should be inserted and both cortices should be drilled. Then a transfixation pin should be inserted by using a low speed (150rpm) drill until the pin tip emerged from the far cortex. Emergence could be determined by palpation and some spatial appreciation. The pin should be placed through the healthy skin whenever possible avoiding abraded or lacerated areas especially while placing pins in wounds. The most proximal and distal pins should be placed first, followed by the connecting bar and the total number of clamps intended for use in the frame design and the bone fragments were reduced and aligned. The remaining pins should be applied sequentially through the clamps to the connecting bar.

2.12.3 Technique for applying acrylic external skeletal fixators

Okrasinski *et al.* (1991) described the construction of acrylic fixators by placing a plastic tube over the fixation pins. The liquid acrylic resin prepared as per the manufacturer's direction was poured into the plastic tube and allowed to harden.

Tomlinson and Constantinescu (1991) reported that most distal and proximal pins are inserted first. If tubing is to be used as a mold, the second and subsequent pins should be driven through the tubing before driving into the bone, which should be done in sterile manner. After reduction, the mixed acrylic has to be loaded in a syringe and injected into the tubing. To prevent skin erosion and to allow a wire cutter to pass under the bar to cut, the tubing should be positioned far enough from the skin. A satisfactory result could be obtained if a distance of 5 to 10 millimetres is allowed between the skin and acrylic bar.

Ross and Matthiessen (1993) mentioned that depending upon the size of the animal, acrylic connecting bar was prepared by mixing the methylmethacrylate to a doughy consistency and placed over the exposed pins in the form of a cylinder at about 1.0 to 2.5 cm space between the skin and acrylic connecting bar. Generally, the cylinder of methylmethacrylate was 2 to 2.5 times the diameter of the bone being repaired.

Martinez *et al.* (1997) reported that to reduce the thermal effects of acrylic on the tissues the acrylic column should be positioned 10 mm or greater from the skin.

Piermattei and Flo (1997) suggested a biphasic technique in order to overcome the difficulty in maintaining fracture reduction during attachment of acrylic column and the hardening of acrylic. In phase I, fracture was reduced and pins inserted. Stainless steel clamps and connecting bars were attached to the pins. It was found not necessary to attach all fixation pins to this temporary connecting bar. The radiographic confirmation of the reduction could be obtained, if desired. The acrylic column was used to join all pins. After acrylic got hardened, the temporary clamps and bar were discarded.

Williams *et al.* (1997) demonstrated the preparation of acrylic column by using a corrugated plastic tube which was sealed at the bottom and positioned perpendicular to the pins. Polymethylmethacrylate made by mixing the powder and liquid monomers in a two to one ratio for 90 seconds was used to fill the column tubing by gravity flow. To facilitate removal of any potential air pockets, an applicator stick was then submerged in the column and then removed.

Dixon and Bone (1998) recommended the temporary reduction of fracture with clamps and connecting bars before the application of methylmethacrylate connecting column. Once the methacrylate had set (eight to ten minutes), the clamps and connecting bars were removed and the excessive fixation pin length was cut off.

Johnson and Hulse (2002) recommended a one stage and two stage technique for application of acrylic splints. In single stage technique, after reduction of the fracture, acrylic was poured into the column and allowed five to ten minutes for the acrylic to cure. In two stage technique, after reduction of fracture, the tube was placed over the ends of the fixation pins. But before pouring acrylic into the column, a temporary stainless steel alignment frame was constructed and added to the fixation pins outside the column moulding tubes. Then Radiographs were taken to assess the fracture reduction. If satisfactory; acrylic was poured into the column and allowed to cure.

2.13 POSTOPERATIVE CARE

VanEe and Geasling (1992) opined early scab formation around the pin tract and discouraged regular cleaning around the pins and suggested regular checking of the clamps for loosening and tighten them if required to prevent implant failure.

Anderson *et al.* (1993) suggested the application of soft padded bandages around the external skeletal fixator after the surgery for removal of drainage around the pins, to protect the surgical wound and to prevent self mutilation. For the first week the bandages were changed daily, then as needed depending on the amount of drainage around pins and soilage. The skin-pin interface was cleaned each time the bandage is changed.

Butterworth (1993) reported that postoperative care of the external fixator is minimal. Usually a light discharge from the pin tracts will generally form a crust which seals the pin-skin interface. In case of more copious discharge, surrounding skin area could be bathed at regular interval avoiding the pin-skin interface.

Ross and Matthiesen (1993) recommended intravenous administration of broad spectrum antibiotics preoperatively and oral administration for 5-7 days postoperatively.

According to Harari *et al.* (1998) in case of pin tract infection, systemic administration of cephalosporin at the rate of 10mg/lb orally thrice daily for 10 days was recommended.

Roush and McLaughlin (1998) recommended one time administration of a first generation cephalosporin at 20mg/kg intravenously and 20mg/kg intramuscularly to provide prophylactic antibiotic coverage for upto five hours of open reduction of fractures.

According to McLaughlin and Roush (1999) the patient's activity should be restricted after fixator application to prevent breakage of transfixation pins. They recommended leash walking of dogs to avoid joint stiffness.

After percutaneous transfixation of the tibia, Carneiro *et al.* (2001) evaluated the post-surgical treatments of bone percutaneous transfixation in dogs and found that dogs treated with a 0.9% sodium chloride solution showed little purulent exudation, while dogs treated with 0.2% 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.

Rochat (2001) suggested daily cleaning of pin-skin interface with dilute chlorhexidine acetate or hydrogen peroxide to allow drainage of exudates until healthy granulation bed developed and scab formation no longer existed.

To control orthopaedic infection Johnson and Hulse (2002) stated the usage of cefazolin 22mg/kg IV, IM or SC at six to eight hours interval as the prophylactic antibiotic.

2.14 EVALUATION OF THE STUDY

2.14.1 Clinical evaluation

Radiographic signs of osteomyelitis were observed by Johnson *et al.* (1989) in some cases of fractures treated with external skeletal fixation, but clinical signs like non weight bearing, swelling, pain and drainage at the fracture site were observed only in one out of twelve dogs.

VanEe and Geasling (1992) reported that the indication of excessive drainage around a pin in the postoperative evaluation are premature pin loosening, excessive skin tension across the pin or large amounts of muscle mass trying to move across the pin during ambulation. Re-evaluate the condition of the fixator and tightness of the clamps.

The degrees of lameness as defined by Sumner-Smith (1993);

0 : Sound
1 : Occasionally shifts weight
2 : Mild lameness at a slow trot, none while walking
3 : Mild lameness while walking
4 : Obvious lameness while walking, but places the foot when standing
5 : Degrees of severity
6 : Degrees of severity
7 : Degrees of severity
8 : Degrees of severity
9 : Places toe when standing, carries limb when trotting
10 : Unable to put the foot on the ground

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

The various clinical signs and its implication were described by Harari *et al.* (1998) and mentioned that in pin tract sepsis; there would be persistent purulent drainage, soft tissue inflammation and patient discomfort. Acute onset of lameness in postoperative healing period indicated osteolysis around pins and pin migration. Myotendinous damage was to be suspected in excessive pin tract drainage with reduced limb activity. Weekly examination of the fixator was recommended and any loose pins or clamps were tightened. In addition, loose pins characterised by bone lysis and patient discomfort should be removed.

2.14.2 Radiographic evaluation

Kantrowitz *et al.* (1988) observed radiographic appearance of pin tract osteomyelitis as a zone of radiolucency surrounding the pin with adjacent periosteal reaction.

Ross and Matthiesen (1993) recommended immediate postoperative radiographs for examination of fracture reduction, placement of pin and joint alignment. In addition appendicular injuries were radiographed every three to four weeks until healing was complete.

Johnson *et al.* (1996) noticed that the mean time to bone union or bridging of comminuted fractures with callus on using external fixation was found to be 11.4 weeks. Radiographically, the type of bone healing observed using external fixation was endosteal callus and uniting callus formation. Periosteal callus formation was minimal.

It was noticed by Roush and McLaughlin (1998) that early signs of fracture healing included periosteal reaction near the fracture, callus formation at fracture site, minor resorption and remodelling of fracture ends or primary bridging of a rigid stable fracture with woven bone.

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

Langley-Hobbs (2003) mentioned immediate postoperative radiographs should be taken and assessed for the four A's- Apposition, Alignment, Angulation and Apparatus. Follow-up postoperative radiographs also were taken and thorough evaluation for six A's- Apposition, Alignment, Angulation, Apparatus, Activity and Architecture were carried out.

On studying the closed and limited approaches to the fracture treatment with external fixator, Ozsoy and Altunatmaz (2003) noticed that the fractures heal by the formation of a large periosteal and endosteal callus.

2.14.3 Haematological evaluation

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

2.14.4 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 reported a significant increase in the serum alkaline phosphatase concentration at seventh and fourteenth postoperative days and returned to normal by sixth postoperative week.

The finding of Kumar *et al.* (1992) was that there was a significant decline in plasma calcium and inorganic phosphorus during the healing period of 21 days in fracture cases in dogs.

Serum calcium, phosphorus and alkaline phosphatase level were analysed postoperatively by Chandy (2000) and observed no variation in the serum calcium and phosphorus level. But serum alkaline phosphatase level showed a significant increase from the preoperative day to 28 days.

2.15 POSTOPERATIVE COMPLICATIONS AND THEIR MANAGEMENT

Vaughan (1975) made study on several complications associated with internal fixation of fractures in dogs and observed stiffness of stifle following femoral fracture repair especially in actively growing dogs when complicated by infection. This may also be due to direct penetration of the joint by intramedullary pin either during surgery or later.

Egger *et al.* (1986) observed quadriceps contracture and stifle extension with the use of Type I double connecting bar configuration on long bone fractures in dogs.

Fox (1986) reported that using Kirschners splint has potential complications and limitations, which include pin tract infections, premature pin loosening, breakage of appliance, focal osteomyelitis, or excessive skin ulceration.

Heim *et al.* (1992) studied the use of external fixation in open fractures and found that fractures, which does not heal within four to six months was considered to be a delayed union and absence of union after eight months of fracture treatment was considered to be nonunion or pseudoarthrosis.

With the use of multiple pin and methylmethacrylate external skeletal fixation for the treatment of orthopaedic injuries in dogs and cats, Ross and Matthiesen (1993) reported breakage of acrylic connecting column and other complications such as pin loosening, pin tract drainage, infection, fixation failure, ostemyelitis, angular limb deformities, malunion, delayed union and nonunion.

Johnson *et al.* (1996) noticed osteolysis around pin tract that was more frequently encountered around pins placed proximal to the fracture line. But despite osteolysis, dogs were able to use limb while fixator was in place.

As noticed by Piermattei and Flo (1997) pin loosening was the major postoperative complication following external fixator application. They opined that loosening of pins was caused by soft tissue interference or with instability of the fracture and recommended removal of pins when it loosened.

Sequin *et al.* (1997) found that pin loosening and pin tract infections were the common complications of external skeletal fixation. They observed fracture along the pin tract, which were caused by several predisposing factors that included intracortical positive profile pin placement, usage of pins greater than 20 percent of the bone diameter, unrestricted patient activity and subsequent fence entanglement.

Common complications of external fixators noticed by Harari *et al.* (1998) were pin tract sepsis, premature pin loosening and soft tissue puncture. According to him, osteolysis around pin tracts resulted in micromovement of the pins within the bone (loose pins) causing bone resorption.

Johnson and DeCamp (1999) reported pressure necrosis of skin when the connecting bar and clamps were placed much close to the skin surface to allow for postoperative edema. Thorough knowledge of regional anatomy for proper placement of transfixation pins is essential especially through neurovascular bundles or muscle/tendon structures, which would lead to soft tissue impalement.

Based on the information obtained from case records and radiographs, Stigen (1999) classified complication arising from intramedullary pinning as: instability, infection and muscle fibrosis.

Clasper *et al.* (2001) suggested that fluid accumulation around the pin-bone interface significantly contributed to spread of bacteria from superficial pin tract to the medulla of the bone.

In the study using external skeletal fixation to repair long bone fractures, complications observed by Rochat (2001) were premature pin loosening, pin tract infection, pin breakage, neurovascular injury, iatrogenic fracture, delayed union, poor limb function, muscle atrophy and loss of reduction.

Pin loosening, pin-base infection, valgus deformation, nonunion and ankylosis are various complications, noticed with external fixator application, by Ozsoy and Altunatmaz (2003)

Julie (2005) observed pin loosening and implant failure by breakage of acrylic column occurred while acrylic column was used for immobilization of femoral fractures.

2.16 REMOVAL OF IMPLANTS

In the combination technique of external fixation with intramedullary pin, Fox (1986) recommended the removal of fixator before the intramedullary pin when rotational stability is obtained. If the external fixation was a primary fixation device of immobilization, it should be removed only after satisfactory evidence of clinical and radiographic healing.

For removal of acrylic ESF, Okrasinski *et al.* (1991) reported that it could be done with an oscillating cast saw or a similar device. Fragments released by the saw are hot and might burn the animal or personnel and suggested the pieces still attached to fixation pins serves as a convenient handles for pin removal.

St-Jean *et al.* (1992) suggested that inorder to prevent displacement of the bone fragments, the external fixator must be in place until sufficient bony callus has developed.

VanEe and Geasling (1992) preferred sedation rather than general anaesthesia for removing the fixator device.

Ross and Matthiesen (1993) suggested the removal of fixator pins after the animals were heavily sedated with both a tranquilizer and an analgesic. Also complete radiographic and clinical union of fracture should also be considered for its removal. Fixator was removed by cutting the pins with pin cutter and the pins were removed using hand chuck or pliers.

Butterworth (1993) found that clinical union usually precedes radiographic union. He recommended that, for external fixator removal, clinical union alone had to be considered.

Johnson *et al.* (1996) reported the mean time between surgery and removal of external fixator was 14.7 weeks using closed reduction and Type II external fixation for comminuted fractures of radius and ulna in dogs.

According to Ozsoy and Altunatmaz (2003) regular postoperative radiograph should be taken and evaluated for assessing sufficient callus formation before removing the fixator.

Materials and Methods

3. MATERIALS AND METHODS

3.1 SELECTION OF CASES

The study was carried out in eight clinical cases of complete fracture of long bones, especially femur in dogs, irrespective of their age and sex. Cases presented to the Veterinary Hospitals of Mannuthy and Kokkalai formed the clinical material. The study was carried out during the period from April 2005 to June 2006.

3.2 BROAD OUTLINE OF WORK

After confirmation of the fracture by radiography, the patients were subjected to the treatment under general anaesthesia. All the animals were prepared by withholding food and water for 12 hours prior to operation. Fractures were evaluated and managed with Type IA external skeletal fixation in combination with intramedullary pinning using acrylic or stainless steel connecting bar according to the body weight of the animal. These animals were followed up for a period of eight weeks and the observations were recorded before and immediately after surgery and at fortnightly interval, there after. During the follow up period, animals were subjected to clinical, radiological, haematological and serum biochemical evaluation, both preoperatively and postoperatively and clinical and radiological observations were recorded fortnightly. Implants were removed based on the radiographic healing.

3.3 HISTORY TAKING

In each case, the signalment, anamnesis and symptoms noticed by the owner were recorded.

3.4 PREOPERATIVE CONSIDERATIONS

Preoperatively all the animals underwent thorough physical examination and any life threatening injuries presented were attended first. If needed, surgery was postponed until the general condition of the patient was improved. All the animals were prepared by withholding food and water for 12 hours prior to the operation.

3.4.1 Patient evaluation

3.4.1.1 Clinical observations

Animals under the study were evaluated by their general clinical condition, functional limb usage, nature of peripheral lymph nodes, pain at the fracture site, deficit in proprioceptive reflex etc., Degrees of lameness observed were graded according to Sumner-Smith (1993).

3.4.1.2 Physiological parameters

All the physiological parameters including Rectal temperature (^{0}C), pulse rate (per minute), respiration rate (per minute), capillary refill time (CRT) in seconds and colour of mucous membrane were recorded.

3.4.1.3 Radiographic evaluation

Plain lateral and craniocaudal radiographs were taken by including the joints proximal and distal to the bone involved. Radiographs were analysed and the fracture configuration and displacement if any, were recorded.

3.4.2 Selection of immobilization materials

3.4.2.1 External fixator configurations adopted

The type of external fixator configuration adopted was unilateral uniplanar (Type IA) external fixator in combination with intramedullary pinning. The connecting bar, acrylic or stainless steel was decided according to the body weight of the animal. Those dogs below 15 kg body weight alone were treated with acrylic connecting bars.

3.4.2.2 Fixation pins

Kirschner pins were used as fixation pins in most cases. The fixation pins were selected so that they occupied 20-30 per cent of the diameter of the bone. In one case Schanz screws (end threaded trocar pointed negative profile pins) were used as fixation pins (Plate 1). The required size of the pins was selected based on the lateral radiograph.

3.4.2.3 Stainless steel clamps, connecting bars and wrench

Stainless steel single clamps suitable for the fixation pins were selected. Steinmann pins or connecting bars of suitable size were used as connecting bars. Wrench of suitable size was used to tighten the clamps (Plate 1).

3.4.2.4 Acrylic column moulding tube

As mentioned by Julie (2005) commercially available corrugated plastic tubes of one centimetre inner diameter were used as a mould for the acrylic (Plate 2). After cutting the tube of appropriate length, one end of the tube was sealed by heating.

3.4.2.5 Polymethylmethacrylate

Commercially available dental grade acrylic repair material DPI RR Cold Cure[1] was used for preparing the acrylic connecting bar (Plate 2), which is available as liquid and powder monomers in separate containers (Piermattei and Flo, 1997).

3.4.2.6 Accessories for mixing the acrylic monomers and for filling the moulding tube

To measure out the required amount of acrylic monomers, a plastic 10ml measuring cup was used. Stainless steel bowl was used to mix acrylic monomer into a semisolid consistency and filled into the moulding tube using a 10ml syringe.

3.4.3 Preoperative preparation

The skin was shaved completely by including the joints above and below the surgical site. The injured area was scrubbed with povidone iodine scrub

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[1] DPI-RR Cold Cure, Dental Products of India, Mumbai, India.

solution[1], washed and mopped dry. The animal was restrained on lateral recumbency with the surgical site upward. The distal extremity of the limb was covered with sterile drape by including the toes and the site was painted with Tr.iodine and draped (Plate 3). The vascular access was retained throughout the surgery by maintaing i/v infusion with Ringer's lactate solution to the dogs.

3.4.4 Anaesthesia

All the surgeries were done under general anaesthesia. The dogs were premedicated with atropine sulphate[2] at the dose rate of 0.045mg/kg body weight and after 15 minutes, xylazine hydrochloride[3] was given at the dose rate of 2 mg/kg body weight. Anaesthesia was induced with ketamine hydrochloride[4], given intramuscularly at the dose rate of 5mg/kg body weight and the anaesthesia was maintained with intravenous administration of xylazine-ketamine mixture (equal volumes) 'to effect' and muscle relaxation was achieved with intravenous administration of diazepam[5] at the rate of 0.25mg/kg body weight.

3.5 SURGICAL PROCEDURE

3.5.1 Open approach

In the combination study of intramedullary pin and Type IA external skeletal fixation open reduction through craniolateral incision was attempted in all the animals. To allow the manipulation of fragments, the surgical incision was made along the safe corridor, directly over the fracture site. By applying traction and toggling, the fractured ends were reduced to normal alignment and apposition (Plate 4). Bone reduction forceps were used to retain the reduced fragments temporarily.

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[1] Microshield*PVP- Povidone Iodine surgical handwash, 500ml, Johnson and Johnson Ltd., 30, Forjett street, Mumbai
[2] Atropine sulphate injection IP. (0.6mg/ml), Mount Mettur Pharmaceuticals Ltd., India
[3] Xylaxin, Indian Immunologicals Ltd., (20 mg/ml), Guntur dist., Andhra Pradesh, 2ml vial
[4] Ketmin 50, (50mg/ml), Themis Medicare Ltd., Mumbai, 2ml ampoule
[5] Calmpose injection, Ranbaxy laboratories Ltd.,(5mg/ml), Mumbai. 2ml ampoule

3.5.1.1 Application of intramedullary pins

Reduced fracture fragments were retained in normal alignment and apposition temporarily using bone reduction forceps and the intramedullary pin was introduced in a retrograde manner using electrical bone drill (Plate 5). The muscle bellies were separated and the Steinmann pin was introduced with the pointed end first, into the proximal fragments from the fracture site and made exit through the skin. The pin was retracted and taken out and reintroduced in the same fashion with the blunt end first. Once the blunt end reached subcutaneously a small nick was made on the skin so that the pin could exit through the opening. The trocar point was brought in level with the fracture line and then the fragments were brought into apposition by reducing with pointed reduction forceps or manually. The pin was driven further down into the distal fragment and made to seat in the cancellous bone in the distal extremity. Cerclage wire was used to retain the fractured fragments in normal alignment and apposition (Plate 7). The proximal end of the pin was cut as short as possible using pin cutter or left protruding out for the tie-in configuration with external skeletal fixation (Plate 10).

3.5.1.2 Application of fixation pins

The fixation pins were driven into the safe corridors of the respective bones most proximally and distally using electrical bone drill (Plate 6). A minimum of two fixation pins were drilled through each segment of the bone. But in cases where the fragments were too short, only one pin was drilled through that particular segment. If the intramedullary pin interfered with the process of the fixation pin, the position was changed so as to apply the pin at a broader point of the bone. Fixation pins were applied through the skin so that there would be no tension on the skin after closure. The tips of the fixation pins were made to project beyond the transcortex and approximately the length of two threads in the case of Schanz screw. Care was taken to ensure that all pins entering bone penetrated both the cortices completely. As half pins were used, the tip of the pins penetrating the opposite cortex could be judged by feeling the tip at the opposite cortex. Also the resistance offered by the tissue to the drilling gave an idea about the extent of penetration. Low speed, high torque power drill (150 to 400rpm) was used to drill the pins, to reduce thermal necrosis of bone. During open reduction, the drilling site was irrigated with normal saline to minimize thermal injury.

3.5.1.3 Closure of surgical site

The separated muscle bellies were apposed and the fascia was closed with simple continuous sutures using size 1-0 or 2-0 chromic catgut. Subcuticular sutures were applied to reduce dead space using 1-0 or 2-0 chromic catgut. The skin incision was closed with simple interrupted sutures using 1-0 or 2-0 nylon or braided silk.

3.5.1.4 Application of stainless steel external skeletal fixator

The stainless steel connecting bars and clamps were applied in such a way that the clamps were placed about 1 cm from the surface of the skin. Clamps and connecting bars were positioned close to the skin leaving only a small space of one centimetre between them. The stainless steel frame could be fixed to the bone in different methods depending upon the stability of the fracture.

The most proximal and distal pins were placed first. Then the clamps, corresponding in number to the number of pins to be used in the framework, were connected to the connecting bar. This frame was then applied to the bone by connecting the clamps at either end of the connecting bar to the pins at either end of the bone already drilled. These clamps were tightened taking care that the fractured fragments were in correct alignment and apposition. The remaining pins were applied sequentially guided through the clamps in the connecting bar and drilled through the bone (Plate 8). All the clamps were then tightened with the wrench (Harari *et al.*, 1998). The excess length of the connecting bar was either cut using pin cutter or tied-in with intramedullary pin.

3.5.1.5 Application of acrylic connecting bar

The corrugated moulding tube was fixed longitudinally parallel to the long axis of the bone by piercing the tube along its width through the free ends of the pins leaving a small space of one centimetre between the skin and the tube. The tube was tied-in with the intramedullary pin. The limb was held upright and the space between the tube and the skin was packed with moist cotton (Plate 9).

The acrylic monomers were mixed in the ratio of 2:1 by volume. For a one centimetre diameter tube of approximately 15cm length, 30ml by volume of powder and 15ml by volume of liquid were mixed. In the semisolid consistency, the mixture was filled into the tube with a syringe or by pouring through a funnel. A setting time of 10 to 15 minutes was allowed. The fixation pins were cooled during the exothermic phase of acrylic hardening by pouring normal saline.

In animals of less than 15 kg body weight, Type IA fixators with acrylic connecting bar was used. In case of animals more than 15 kg body weight, stainless steel connecting bar was used.

3.6 POSTOPERATIVE CARE

Ceftriaxone sodium[1] was used routinely at the rate of 20mg/kg body weight as intravenous injection on the day of surgery and on the subsequent days as intramuscular injection or Cephalexin[2] tablets orally for atleast five days. Antibiotic therapy was prolonged, whenever needed.

The excess length of the intramedullary pin was cut at the level of skin where tie-in configuration was not used. Projecting pins above the acrylic were cut and removed. Adhesive plaster was used to cover the pin tip.

Entire implants including the suture line and the pin entry points were covered with sterile gauze and secured with adhesive tape.

Owners were advised to restrict the movement of the animal for two weeks after surgery and then to allow on leash walking.

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[1] SAFEVET 500mg injection, Dosch pharmaceuticals private Ltd., Mumbai.
[2] SPORIDEX AF 375 mg tablets, Ranbaxy laboratories Ltd., Gurgaon.

Postoperative evaluation was carried out on the third and tenth postoperative days, whenever possible, and from second week onwards, at fortnightly interval upto eight weeks or until the completion of healing.

The suture lines and the pin entry points were painted with povidone iodine or povidone iodine was infused into the pin tracts when there was discharge from the tract. As the discharge ceased and wound healing noticed, limited dressing was done, taking care, not to disturb the scabs. By 10^{th} postoperative day, the skin sutures were removed.

3.7 REMOVAL OF THE IMPLANTS

The implants were removed after complete fracture healing, confirmed by clinical and radiological evaluation. To remove the implants, animals were sedated with xylazine hydrochloride at the rate of 2 mg/kg body weight after premedication with atropine sulphate at the rate of 0.045mg/kg body weight, both given intramuscularly. As mentioned by (Okrasinski *et al.*, 1991) the acrylic connecting bars and transfixation pins were removed by cutting the acrylic column in between pins and using each piece attached to the pins as handle to unscrew them out of the bone

3.8 EVALUATION OF THE STUDY

Animals under the study were evaluated for clinical, radiological, haematological and serum biochemical studies done at fortnightly interval from the day of surgery. Complications observed, if any, were recorded.

3.8.1 Patient evaluation

3.8.1.1 General clinical condition

The general condition of the animal, condition of the affected limb, weight bearing, posture, position and changes at the site of surgery were recorded.

3.8.1.2 Peripheral lymph nodes

Based on the size of the peripheral lymph node of the affected limb, it was graded as normal, slightly enlarged or enlarged.

3.8.1.3 Pain

The fracture site and the pin entry points were gently palpated. The response of the animal to different levels of pain was assessed and graded as absent, mild, moderate or severe.

3.8.1.4 Test for neurological function

The operated limb was tested for the integrity of nerve supply by testing the sensory, motor and proprioceptive reflexes. The sensory reflex was tested by testing the pain perception by compressing the interdigital space. Motor function was assessed by testing the patellar reflex or tendon reflexes. Proproiceptive reflex of the affected limb was checked and graded as present or absent, following implant removal for the integrity of nerve supply. The reflex was assessed by examining the placing or wrighting reflex of the affected limb, while standing.

3.8.1.5 Functional limb usage

As suggested by Sumner-Smith (1993) the functional limb usage was assessed and graded as 0 to 10.

3.8.1.6 Physiological parameters

Various physiological parameters *viz.*, rectal temperature (^{0}C), pulse rate (per minute), respiration rate (per minute), capillary refill time (seconds) and colour of conjunctival mucus membrane were recorded both preoperatively and on 2nd, 4th, 6th and 8th postoperative weeks.

3.8.1.7 Haematological evaluation

Various haematological parameters *viz.*, haemoglobin concentration, volume of packed red cells (VPRC), erythrocyte sedimentation rate (ESR), total leucocyte count (TLC) and differential count (DLC) were recorded preoperatively and at fortnightly interval for upto eight weeks.

3.8.1.8 Serum biochemical evaluation

Serum calcium, phosphorus and alkaline phosphatase were analysed and recorded preoperatively and on 2nd, 4th, 6th and 8th postoperative weeks.

Photometric determination of alkaline phosphatase was done by kinetic method using serum alkaline phosphatase analysis kit. Serum calcium was estimated by Atomic Absorption Spectrophotometer and Serum phosphorus was estimated by photometric method.

3.8.2 Implant evaluation

3.8.2.1 Apparatus stability

The stability of the fixator to maintain the necessary mechanical configuration during treatment was judged by gross observation and detailed physical examination. The external frame was checked for loosening of the fixation pins and for breakage of acrylic bar. Loosening of pins was judged by gently moving the pins laterally.

3.8.2.1 Patient acceptance

The acceptance of the external fixator by the patients was studied based on tissue reactions and graded as satisfactory or unsatisfactory.

3.8.2.3 Mutilation

Based on the clinical observation and from the history collected from the owner, the incidence of mutilation of the external frame was assessed throughout the observation period.

3.8.2.4 Pin tract drainage

The pin entry and exit points were inspected for any discharge form the pin tracts and classified as serous or pus discharge.

3.8.3 Radiographic evaluation

Two radiographs, lateral and craniocaudal were taken at fortnightly interval upto eight weeks. From the immediate postoperative radiograph, the four A's *ie.,* Alignment of fragments, Apposition of fragments, Angulation between fragments and Apparatus were assessed. From the postoperative radiograph obtained at 2nd, 4th, 6th and 8th postoperative week, the six A's *ie.,* Alignment of fragments, Apposition of fragments, Angulation between fragments, Apparatus, Activity and Architecture at fracture site were assessed.(Langley-Hobbs, 2003).

3.8.3.1 Apposition

From the immediate postoperative radiograph, the accuracy of fracture reduction was assessed from percentage of bone ends in contact and the fracture reduction and apposition were ascertained in the radiographs taken at fortnightly interval also.

3.8.3.2 Alignment and Angulation

From the immediate postoperative radiograph, the straightness in the alignment of the bone was assessed *ie.,* craniocaudal or mediolateral bend, if present, was noticed. Also any degree of rotation between the bone fragments was analysed.

3.8.3.3 Apparatus

The correct implant usage in terms of length, positioning and size of the pins was analysed from the immediate postoperative radiograph. Any implant failure like pin loosening or bending, breakage of acrylic bar or changes in position of fracture fragments were assessed from the radiographs taken at fortnightly interval.

3.8.3.4 Activity

Increase in radiodensity at fracture site, either endosteal or periosteal, indicated the callus formation. From the radiographs taken at fortnightly interval, the evidence of bone healing and callus formation were observed and recorded.

3.8.3.5 Architecture

Analysis of architecture was based on the periosteal reactions or osteolysis present along the length of the bone. Decrease in the radiographic density was considered as the sign of osteolysis and was graded as present or absent based on the examination of the entry and exit points of pins as well as the pin tracts. Periosteal reaction was observed on the basis of radiographic appearance and was graded as mild, moderate or severe.

3.8.4 Statistical analysis of data

The data were analysed using paired 't' test (Snedecor and Cochran, 1985).

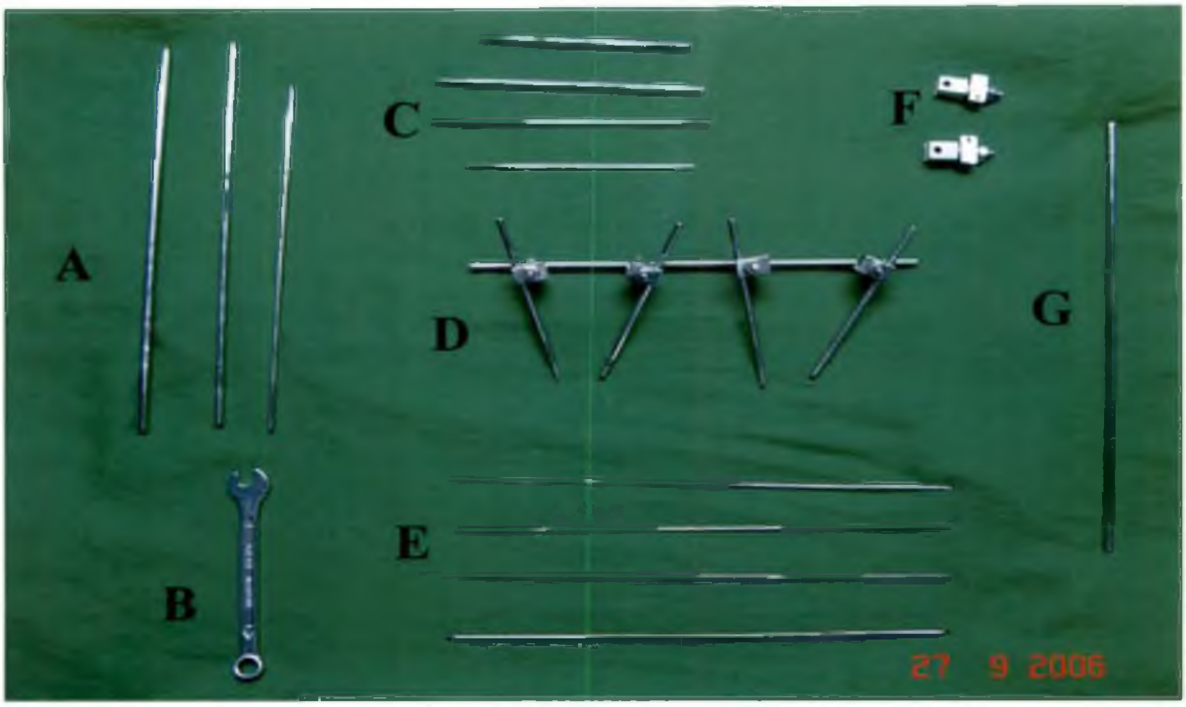

Plate 1. Components of external fixator and intramedullary pins

A. Steinmann pin
B.Wrench
C. Schanz screws
D.External fixator assembly
E. Krischner wire
F. Single clamps
G. Connecting bar

Plate 2. Commercially available polymethylmethacrylate and corrugated flexible pipe

Plate 3. Surgical site - prepared aseptically (Case No. 1)

Plate 4. Fracture site - exposed surgically (Case No. 1)

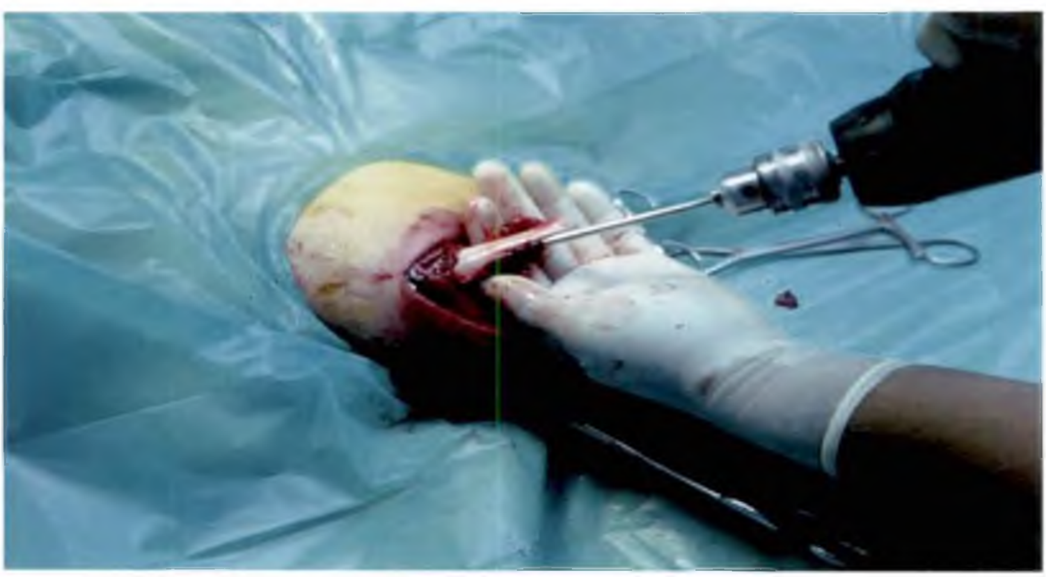

Plate 5. Insertion of intramedullary pin into the proximal fragment (Case No. 1)

Plate 6. Insertion of fixation pin into the distal fragment (Case No. 1)

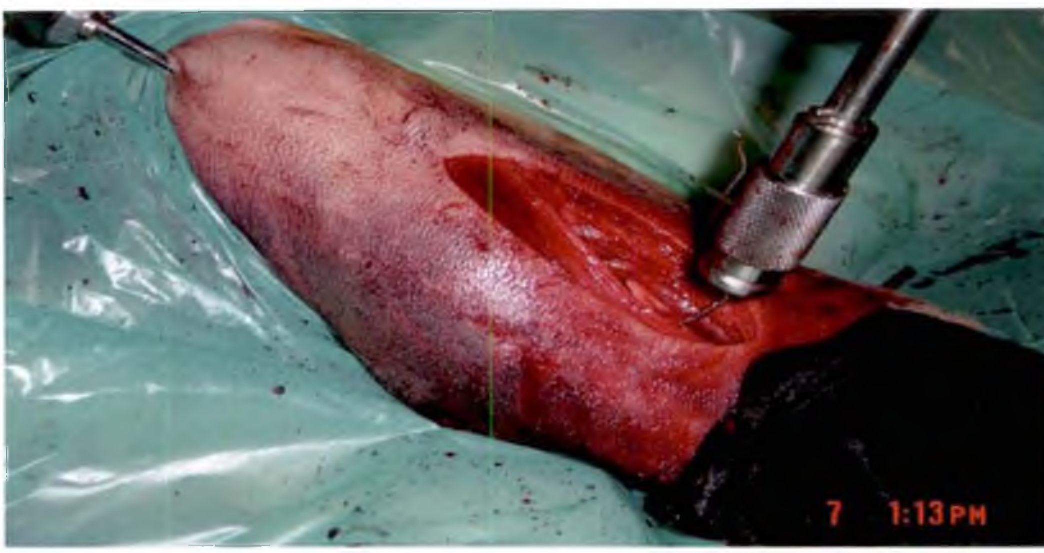

Plate 7. Application of cerclage wire (Case No. 1)

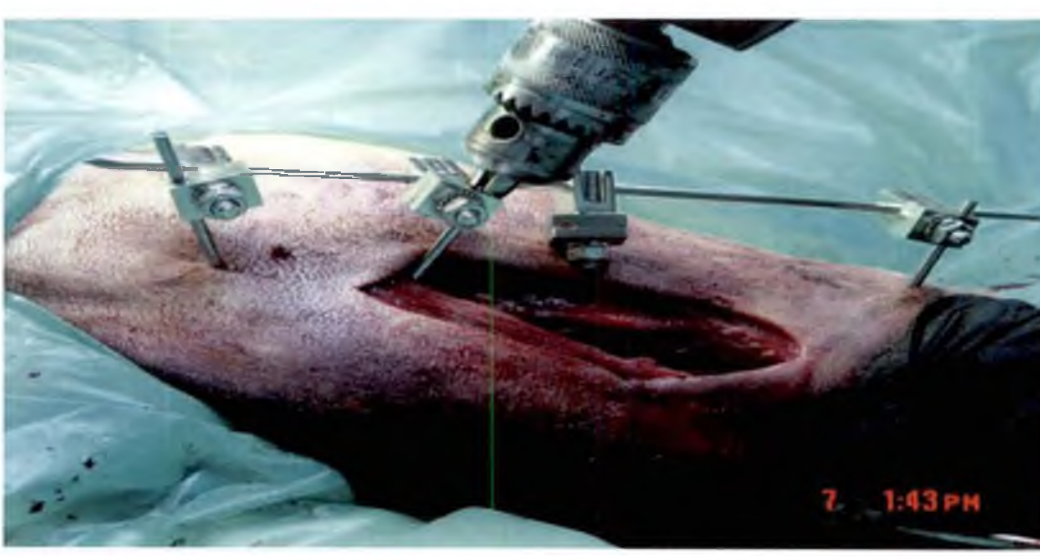

Plate 8. Insertion of fixation pins through the clamps after fixaton of the connecting bar (Case No. 1)

Plate 9. Filling of acrylic into the corrugated pipe (Case No. 2)

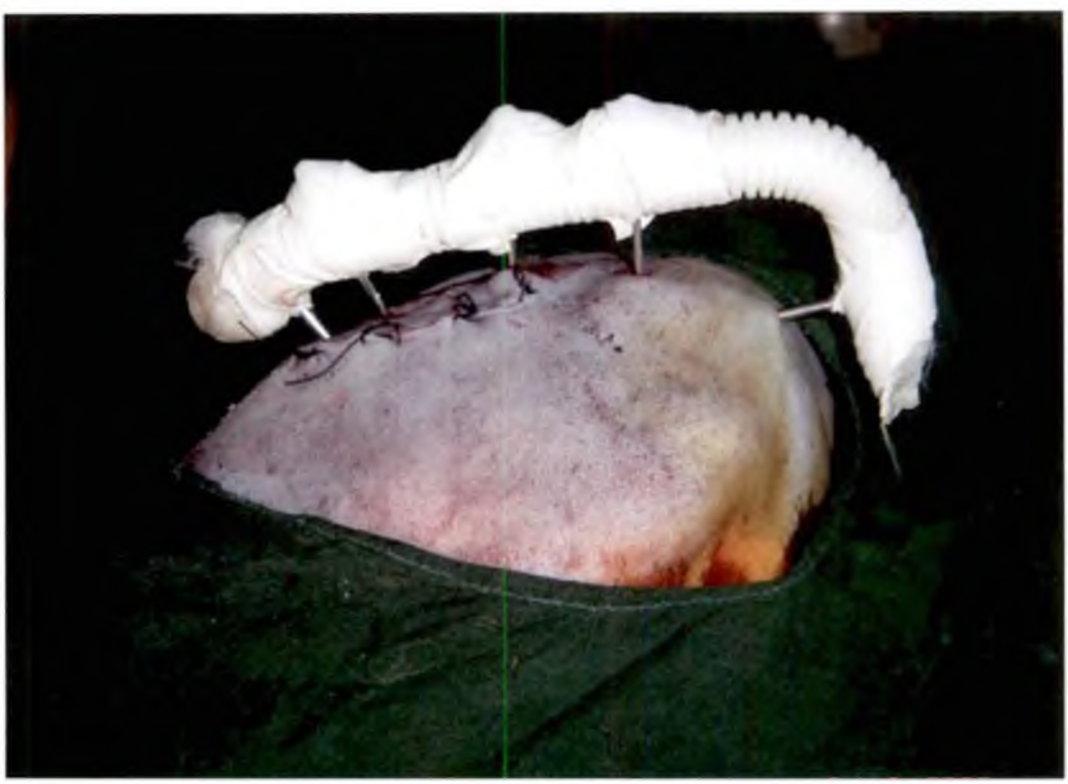

Plate 10. Acrylic external fixation with 'Tie - In' configuration adopted

Result

4. RESULTS

4.1 SELECTION OF CASES

The study was carried out in the Department of Veterinary Surgery and Radiology, during the period of April 2005 to June 2006. Eight clinical cases of complete fracture of long bones, especially femur in dogs irrespective of their age and sex presented to the Surgery Units of Veterinary College Hospitals, Mannuthy and Kokkalai, were selected for the study.

Breeds of dogs selected for the study were German Shepherd Dog (4), Great Dane (2), Spitz (1) and Lhasa Apso (1). The age of the animals ranged from two months to eleven and a half years with 50% of the animals presented were below one years of age. The dogs selected weighed between four and a half to thirty two kilogram body weights. Among those animals affected, four were males (50%) and the remaining four were females (50%).

Automobile accidents and fall from a height were exciting causes for the fracture that was presented for treatment.

The limbs involved in the fracture were the left fore limb in one animal, right hind limb in three animals and left hind limb in four animals.

When presented, the duration of fracture ranged from two days to four weeks. The case presented after 4 weeks was having malunion of tibia and fibula at the middle third.

4.2 TYPES OF FRACTURES ON RADIOGRAPHIC EVALUATION

Among the cases selected for study, six cases were of femoral fracture (75%) and one case each of fracture of humerus (12.5%) and tibia and fibula (12.5%). Five of the fractures were oblique (62.5%) which included a malunion of the tibia and fibula, two transverse (25%) and one comminuted fracture with a butterfly fragment (12.5%).

4.3 SELECTION OF MATERIALS

4.3.1 Fixation pins

From the lateral radiograph of the fractured bone, pins were selected such that it occupied 30% of bone diameter. The pins selected were suitable in all the cases. Smooth pins (K wires) were used in all cases except in Case No. 3 and its usage was found to be satisfactory. In Case No. 3, Schanz screws were used as the fixation pins (Plate 1).

4.3.2 Acrylic column moulding tube

The corrugated flexible pipes of one centimeter diameter were used as the mould for the acrylic (Plate 2). This was found effective as mould for acrylic in animals with body weight less than 15kg.

4.3.3 Type of external skeletal fixation adopted in combination with intramedullaty pin

Type IA configuration was adopted in all cases of study. Stainless steel connecting bar with tie- in configuration was used in Case No. 3. Stainless steel connecting bar without tie-in configuration was used in Case Nos. 1, 6 and 8. Acrylic connecting bar with tie-in configuration was used in Case Nos. 2, 4, 5 and 7 (Plate 10).

4.4 EVALUATION OF THE TECHNIQUE

4.4.1 Anaesthetic protocol

There was satisfactory use of anaesthetic protocol followed for all cases of surgical intervention. Premedication was done using Atropine sulphate at the dose rate of 0.045mg/kg body weight intramuscularly. Xylazine hydrochloride was given intramuscularly after 15 minutes at the dose rate of 2 mg/kg body weight. General anaesthesia was induced with ketamine hydrochloride at the dose rate of 5mg/kg body weight. An equal volume of xylazine-ketamine mixture and diazepam (0.25mg/kg body weight) were used to maintain anaesthesia with intravenous administration. The anaesthesia was maintained throughout the period of surgery with incremental doses of xylazine-ketamine mixture and diazepam, administered 'to effect'.

4.4.2 Surgical approach for fracture treatment

In the combination technique of intramedullary pin and Type IA external skeletal fixation open reduction was attempted in all cases through craniolateral incision.

As the fracture fragments in Case No. 1 was highly unstable even after the application of intramedullary pin, cerclage wiring was done to retain the reduced fragments in apposition and alignment before application of external fixator (Plate 7). But mild angulation between the fragments was noticed in Case No. 7, in the immediate postoperative radiograph, where no cerclage wiring was employed.

4.4.3 Insertion of Intramedullary Pin

Steinmann pin of suitable size that occupied 70% of the medullary cavity at the isthmus was selected through the lateral radiograph. Retrograde intramedullary pinning technique was used to place the pin into the medullary canal (Plate 5). While undergoing intramedullary pinning, another pin of similar length was compared to assess the safe depth of penetration into the intramedullary canal.

4.4.4 Insertion of fixation pins

Pins were inserted through the safe corridor using slow speed, electric bone drill (Plate 6) and found very satisfactory without undue injury to vital anatomical structures.

In all cases except Case Nos. 1 and 2, two pins were drilled through each fragment as the fracture site was located at the distal diaphysis of Humerus and femur respectively. In Case No. 1, three pins were driven through the proximal fragment and one pin in the distal fragment. In Case No. 2, two pins were drilled through proximal fragment and one pin in the distal fragment. Even though only one pin was drilled through the distal fragment, it did not affect fracture stability significantly.

Pins were inserted atleast one centimeter away from the fracture site except in Case Nos. 2 and 5, where the pins were found inserted at the fracture site.

The pins were drilled almost parallel to each other in Case Nos. 2, 4, 5 and 7. In Case Nos. 1, 3, 6 and 8, pins were drilled at an angle of 70 degree from the long axis of the bone, at least two centimetres away from the fracture site.

Digital palpation to confirm the pin exit through the transcortex was effective in fixing the pin at the transcortex.

4.4.5 Application of stainless steel external skeletal fixator

In the present study, stainless steel connecting bars were used in heavier animals weighing more than 15 kg. It was applied in Case Nos.1, 3, 6 and 8 where the body weight of these animals were 31kg, 20kg, 32kg and 20kg respectively.

The methods suggested by Harari et al. (1998) were used for connecting stainless steel connecting bar. The most proximal and most distal pins were drilled first followed by connecting the connecting bar with required clamps (Plate 8). Then remaining pins were guided through the clamps in the connecting bar and were tightened ensuring proper alignment and apposition between fragments. The technique was found satisfactory in inserting the connecting bar and fixation pins.

4.4.6 Application of acrylic connecting bar

Acrylic connecting bars were used in animals weighing less than 15 kg. It was applied in Case Nos. 2, 4, 5 and 7 where the body weight of the animals were 13, 4.5,15 and15 kg respectively.

The preparation of acrylic as a connecting bar was inexpensive and simple. One end of the tube was sealed and the other end kept open. Tube was fixed onto the fixation pin and was tied to the intramedullary pin also. The open end of the tube was placed distally. Then the leg was lifted upwards so that the open and of the tube will be held above and the sealed end will be below (Plate 9). Adequate consistency of acrylic was prepared by mixing the acrylic monomer in 2:1 ratio by volume. The prepared acrylic was poured into the tube which hardened in 10 to 15 minutes. The acrylic bar was kept at about one centimeter distance from the skin and this did not cause any complication postoperatively.

4.4.7 Postoperative care

Postoperatively, the pin entry point and the suture lines were infused with 5 to 10 ml gentamicin solution. Sterile dressing pad was placed around the pin tract and on the suture line and bandaged after securing with adhesive tape. Postoperative infection was satisfactorily controlled with the paranteral use of Ceftriaxone injection at the dose rate of 20 mg/kg body weight and oral Cephalexin at the dose rate of 20 mg/kg body weight for upto 8 to 10 days. Discharge from the pin entry points and the suture lines were cleaned regularly with 5% povidone iodine solution. As the discharge from the pin entry point ceased, cleaning was done only when needed. By 10th postoperative day, the skin sutures were removed in all the animals.

4.4.8 Removal of implant

Implants were removed based on the radiographic union and the evidence of visible callus at the fracture site.

The fixation pins were removed manually. But the intramedullary pin was removed using Jacobs hand chuck in all cases except Case Nos. 2, 4, 5 and 7, where tie-in configuration was used. In these cases, the intramedullary pin was removed using forceps. Both the external fixator and the intramedullary pin were completely removed except in Case No. 8, where the intramedullary pin was left in situ.

The implants were completely removed by the eighth weeks in Case Nos. 1, 2, 7 and 8. In Case No. 4 implants were removed by sixth week based on the clinical and radiographic evaluation of fracture site and functional limb usage.

The implants were removed by sixth week in Case No. 6 as a result of spondylosis and to avert the animal lie on the side of operated limb. Removal was also decided based on clinical union of the fracture site.

Staged removal of the implants was followed in Case No. 5 as there was valgus deformity as a result of tie-in configuration. By sixth week, intramedullary pin and second fixation pins were removed leaving the other pins intact and the later was removed by eighth week.

There was an incidence of self mutilation in Case No. 2, however it does not interfere with callus formation and subsequent limb usage. On second postoperative day, the animal has broken the acrylic column between the intramedullary pin and the first fixation pin. This was later joined using the adhesive tape. Again by second week, animal has removed the distal fixation pin and acrylic column, which was reapplied later. On the eight postoperative week, animal has removed the implants completely leaving a larger wound cavity in intramedullary pin tract. This wound cavity was healed on by tenth postoperative week with the antibiotics.

Sedation with xylaxine (2 mg/kg body weight) was used to remove the implants in Case Nos. 1, 4, 5, 7 and 8.

4.5 PATIENT EVALUATION

Evaluation of animals were done every two weeks either upto eight week or until implant removal and later on, if needed. During this period, any noticeable observations were recorded.

4.5.1 General clinical condition

All the animals were alert and active preoperatively and the Case No. 6 showed evidence of spondylosis on preoperative radiograph and by second postoperative week the animal was on left lateral recumbancy and has developed pressure wounds on the left side. It was treated with steroids, analgesics and ultrasound therapy for four weeks without any improvement.

Case No. 5 did not show any radiographic signs of callus formation between the fractured fragments even by eighth week and progressed to nonunion. This animal also showed valgus deformity of the operated limb by fourth week.

Case No. 3 developed signs of parvo viral enteritis (confirmed by post mortem) and was succumbed to death by sixth week.

Case Nos. 4 and 8, developed quadriceps muscle contracture (Plate 16), on the operated limb following intramedullary pinning with external fixation. Case No. 4 showed evidence of lumbar pain that underwent ultrasound therapy and electrical stimulation.

Case No. 7 showed high temperature by sixth week and the popliteal lymph nodes were palpable externally. Blood examination revealed no evidence of parasites. Animal was put on cephalosporin antibiotics for one week and was normal there after.

4.5.2 Functional limb usage

By third postoperative day, dogs of Case Nos. 2, 4, 6, and 7 were seen to make slight ground contact with the leg.

Case No. 1 showed evidence of radial nerve paralysis and until eighth week was found dragging the limb. During this period animal was not bearing weight on the limb and found touching the toe on the ground while at rest. But, two weeks after implant removal onwards, animal started bearing weight on this limb and showed signs of recovery from radial paralysis.

In Case No. 2, although implants were disturbed by the animal, the degree of weight bearing improved significantly. Until fourth week the animal was not able to bear weight completely but occasionally while trotting, there was slight ground contact. However, it showed progressive improvement in limb usage by sixth week and had sound limb usage after implant removal.

Complete weight bearing and limb contact with the ground was absent in Case No. 3 until fourth week.

Case Nos. 4 and 8, showed good improvement in weight bearing by second week but it showed evidence of quadriceps muscle contracture. Case No. 4 had lumbar pain by second postoperative week.

Through out the observation period, Case No. 5 had obvious lameness while walking, but placed the foot while standing. Subsequently, it showed complete absence of callus formation that led to nonunion.

Quadriceps muscle contracture was noticed in Case Nos. 4 and 8 with inability to flex the stifle joint.

Case No. 6 started placing its limb on the ground by third postoperative day and by second week had some improvement in weight bearing. But subsequently the animal was recumbent and developed bed sore due to spondylosis.

Case No. 7 started bearing weight partially on the ground by first postoperative day itself and showed good improvement in weight bearing later.

4.5.3 Peripheral lymph nodes

Peripheral lymph nodes were normal in size throughout the observation period in all cases. Popliteal lymph nodes were slightly enlarged in Case Nos. 7 and 8 by sixth and fourth postoperative week respectively. Although blood examination revealed no signs of Ehrlichia, they were treated with Doxycycline at the dose rate of 10 mg / kg body weight daily orally for two weeks and became normal afterwards.

4.5.4 Pain at the fracture site

On the day of presentation, all dogs normally had severe pain on palpation at the fracture site. Case Nos. 1 and 6 evinced mild pain at the fracture site through out the observation period. From second week of observation onwards, Case Nos. 2, 3, 4, 5, 7 and 8 evinced no pain on palpation.

4.5.5 Proprioceptive reflex

On the day of presentation, Case No. 1 lacked proprioceptive reflex completely and manifested the symptoms of radial nerve paralysis. The dog started showing signs of radial paralysis from second week onwards following the removal of implants.

The reflex was sluggish in Case Nos. 3, 5 and 6 through out the observation period and was moderate in other animals.

4.5.6 Physiological parameters

Preoperatively and throughout the observation period, the physiological parameters were within the normal range.

4.5.6.1 ***Respiration rate***

The variations in respiration rate were within the normal range and respiration rate recorded was 32.37 ± 1.60 on the day of presentation. The respiration rate recorded on immediate, second week, fourth week, sixth week and eighth postoperative weeks were 30.25 ± 1.43, 31.62 ± 1.16, 33.75 ± 2.31, 32.83 ± 1.61 and 30.00 ± 0.89 respectively.

4.5.6.2 ***Pulse rate***

The variations in pulse rate were within the normal range and pulse rate recorded was 99.12 ± 3.20 on the day of presentation. The pulse rate recorded on immediate, second week, fourth week, sixth week and eighth weeks were 94.25 ± 2.05, 95.00 ± 3.40, 95.75 ± 1.38, 97.66 ± 1.63 and 99.33 ± 1.15 respectively.

4.5.6.3 ***Rectal temperature***

The variations in rectal temperature (^{0}C) were within the normal range and rectal temperature (^{0}C) was 39.16 ± 0.26 on the day of presentation. The rectal temperature recorded on immediate, second week, fourth week, sixth week and eighth weeks were 38.57 ± 0.10, 38.80 ± 0.21, 39.00 ± 0.14, 38.83 ± 0.25 and 38.78 ± 0.18 respectively.

4.5.6.4 *Capillary refill time*

In all cases, the capillary refill time was less than one second to one second on the day of presentation and through out the observation period.

4.5.6.5 *Colour of mucous membrane*

In all cases, the conjunctival mucous membrane was pale pink in all the animals preoperatively and through out the observation period

4.6 IMPLANT EVALUATION

The implants were evaluated during the postoperative period and the results were represented in table 6.

4.6.1 Apparatus stability

The acceptance and stability of the implants were satisfactory in all cases except in Case Nos. 2 and 6, where pin loosening and bending were the common complications observed.

In Case No 2, on second postoperative day, there was severe mutilation that resulted in breakage of acrylic column at the proximal end between the intramedullary pin and the first fixation pin. This was joined together by adhesive tape. Again by second week the animal had broken the acrylic at the distal end (Plate 13), that resulted in loosening of the distal pin, which was reapplied later. On eighth postoperative week the animal had completely removed the acrylic column, without causing any adverse effect on fracture healing.

Case No. 6 showed evidence of spondylosis on preoperative radiograph and by second postoperative week the animal was recumbent. This caused pin loosening and bending.

4.6.2 Patient acceptance

In all cases, patient acceptance towards the apparatus was satisfactory through out the observation period. No animal had developed tissue reaction to the apparatus.

4.6.3 Mutilation

There was severe mutilation observed in Case No. 2. Until the implant removal, mutilation and chewing on the implant was observed. However this does not interfere with callus formation and subsequent limb usage. On second postoperative day, acrylic column was broken between the intramedullary pin and first fixation pin. This was later joined using the adhesive tape. By second postoperative week, acrylic column along with distal fixation pin was removed by the animal (Plate 13). This was reapplied on the same day. Implants were completely removed by the animal on eighth week of presentation, leaving a larger wound cavity at the exit point of the intramedullary pin tract (Plate 14). This wound was healed subsequently with antibiotics.

Case No. 3 showed tendency to lick the limb during the first two weeks and it resulted in cellulitis on the medial aspect of the limb.

Although bandage was disturbed by all the animals, mutilation of the implants was absent in Case Nos. 1, 3, 4,5,6,7 and 8.

4.6.4 Pin tract drainage

Case Nos. 3, 4, 5 and 7, showed mild pin tract drainage, which subsided without any complication.

On fourth postoperative week, Case No. 8 had maggot wound infestation on the proximal pin tract which had copious pin tract discharge.

In Case No. 1, there was mild serous discharge noticed from the third pin during the fifth postoperative day of observation. By fourth postoperative week, this was aggravated by presence of maggots when copious discharge was present.

In Case No. 2, due to severe mutilation there was mild serous discharge noticed from the distal most pin tract after the distal most pin was removed by the animal on second postoperative week. This was observed through out the observation period, but it was negligible. There was purulent pin tract drainage in the intramedullary tract after the implants were found completely removed by the animal on the eighth week of presentation.

There was evidence of spondylosis on preoperative radiograph in Case No. 6 and the animal was recumbent on the implant side by second postoperative week This caused pin loosening and purulent pin tract drainage especially from the distal two pin tract.

4.7 RADIOGRAPHIC EVALUATION

From the immediate postoperative radiograph, the four A's ie., Alignment, Apposition, Angulation and Apparatus were evaluated and from the successive postoperative radiograph at fortnightly interval upto eighth week. The six A's ie., Alignment, Apposition, Angulation, Apparatus, Activity (fracture gap and callus formation) and Architecture (periosteal reaction and osteolysis) were also evaluated.

4.7.1 Preoperative radiograph:

Case No. 1

Comminuted fracture with a butterfly fragment at distal one third of humeral shaft.

Case No. 2

Simple oblique overriding fracture with a butterfly fragment at distal one third of femoral shaft.

Case No. 3

Simple oblique overriding fracture of tibia and fibula with malunion at middle third. Callus was visible at the fracture site. Cortex was very thin.

Case No.4

Simple oblique overriding fracture at middle third of femur (Plate 12a).

Case No. 5

Simple complete transverse fracture at proximal one third of femoral diaphysis.

Case No. 6

Simple complete overriding oblique fracture of femur at middle third.

Case No. 7

Simple short oblique fracture at middle third of femur.

Case No. 8

Simple complete transverse fracture at proximal one third of femur.

4.7.2 Immediate postoperative radiograph:

Case No. 1

The alignment and apposition between the between the fragments was satisfactory with a mild mediolateral malalignment between fragments. Implant usage was also satisfactory. Cerclage wiring was done to keep the butterfly fragment intact.

Case No. 2

Implant usage was satisfactory with the apparatus properly placed and of correct length and size. Butterfly fragment was not included in the immobilization.

Case No. 3

There was good alignment and apposition between the fractured segments. Implant usage was satisfactory. Tie in configuration was used.

Case No. 4

The apparatus was properly placed and of correct length and size. Alignment and apposition between the fragments was good. Implant usage was perfect (Plate 12b).

Case No. 5

Alignment and apposition between segments were good. Apparatus was properly placed and of correct dimensions. Second pin was found at fracture site.

Case No. 6

Alignment and apposition between the fragments was good. Implant usage was satisfactory.

Case No. 7

Implant usage was satisfactory with slight craniocaudal angulation between the fracture fragments. Apparatus was properly placed and of correct dimensions.

Case No. 8

Implant usage was satisfactory with good alignment and apposition. Apparatus usage was satisfactory with the distal end of the pin reaching upto middle of the medullary canal.

4.7.3 II week radiograph:

Case No. 1

No callus formation could be noticed with evidence of fracture gap. Cerclage wire was loosened and the distal end of intramedullary pin was found away from the fracture site. Periosteal reaction was also absent.

Case No. 2

There was mild periosteal reaction. Fracture gap was visible with no callus formation.

Case No. 3

Both periosteal and endosteal callus could be noticed in tibia, but fracture gap was not completely filled up.

Case No. 4

Fracture gap was faintly visible with the formation of callus. There was good apposition between the fragments (Plate 12c).

Case No. 5

No visible callus could be appreciated between the fragments. Bending of two distal pins noticed at the level of acrylic connecting bar. A fracture gap was present and the fracture fragment margins were indistinct.

Case No. 6

Bone was found splintered between the fragments. Bending of two distal pins noticed. No visible callus could be appreciated.

Case No. 7

There was good callus formation. Fracture gap was faintly visible.

Case No. 8

There was good periosteal and endosteal callus formation. Periosteal reaction present. Fracture gap was faintly visible between the fragments. Implants remained intact.

4.7.4 IV week radiograph:

Case No. 1

Fracture gap was evident with absence of periosteal reaction and callus formation. Distal end of the intramedullary pin still found away from the fracture site.

Case No. 2

Distal pin was removed by the animal. Facture gap was visible with a visible endosteal callus formation.

Case No. 3

Moderate amount of periosteal and endosteal callus could be noticed around the fracture site. The implant was removed by the fourth week.

Case No. 4

Bridging of fracture gap with callus could be appreciated with a perfect apposition between the segments. Thin endosteal callus was visible (Plate 12d).

Case No. 5

No visible callus could be appreciated. Implants remained intact with second pin found at the level of fracture site.

Case No. 6

There was moderate periosteal reaction noticed around the fragments. The malalignment between the fragments still present. There was mild osteolysis around the distal pin tract.

Case No. 7

There was good bridging of fractured fragments with endosteal callus. Fracture gap was not visible.

Case No. 8

Implants reminded intact with the fracture gap filled with callus. There was small line found separating the fragments.

4.7.5 VI week radiograph:

Case No. 1

Fragments were in apposition with absence of callus formation. There was complete absence of periosteal and endosteal reaction.

Case No. 2

Moderate periosteal and endosteal reaction could be noticed. Fracture gap between the fragments was reduced.

Case No. 3

Not available

Case No. 4

Fracture gap was not visible. Cortex was very thin. Implants remained intact (Plate 12e).

The implant was removed by the sixth week.

Case No. 5

The fracture line was still wide with no visible callus formation. Second pin was found in between the fragments. Intramedullary pin and second pins was removed by sixth week.

Case No. 6

Severe periosteal reaction could be noticed around the fragments. Endosteal reaction could also be noticed. Fracture gap was wide with visible callus formation found bridging the gap. Severity of osteolysis around the distal pin tract increased.

Implants were removed by sixth week.

Case No. 7

Cortex was very thin throughout the bone. There was good apposition between the fragments. Osteolysis could be appreciated along the length of the bone.

Case No. 8

Not available.

4.7.6 VIII week radiograph:

Case No. 1

A fracture gap was present and the fragment margins were indistinct. Visible periosteal and endosteal reaction noticed with mild callus formation. Intramedullary pin still found away from the fracture site.

Case No. 2

Distal two pins were removed by animal. Moderate periosteal and endosteal reaction noticed with a visible callus bridging the fractured fragments.

The implants were removed by the eighth week.

Case No. 3

Not available.

Case No. 4

Not available.

Case No. 5

Nonunion of fractured fragments noticed without any visible callus formation.

Case No. 6

Severe periosteal and endosteal reaction could be appreciated around the fragments. Fracture gap was wide.

Case No. 7

Osteolysis could be noticed along the femoral diaphysis. Fragments were in proper apposition with thick callus completely filling the gap. Cortex of the bone was very thin.

Case No. 8

Fracture gap was completely filled with thick callus. Cortex was thin. Implant reminded intact. Calcification of patellar ligament could be appreciated. Mild osteolysis observed along the length of the bone.

4.7.7 X week radiograph:

Case No. 2

Severe degree of periosteal reaction was noticed through out the length of the bone. Fracture gap was faintly visible.

4.8. HAEMATOLOGICAL EVALUATION

The haematological parameters recorded were represented in table 8.

The haemoglobin concentration (g/dl) was 12.75 ± 0.59 preoperatively. It was 11.87 ± 0.51, 11.00 ± 0.46, 11.25 ± 0.31, 12.66 ± 0.28 and 12.83 ± 0.26 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The VPRC (%) was 36.37 ± 1.23 preoperatively. It was 37.00 ± 1.37, 33.87 ± 1.36, 36.50 ± 0.56, 35.83 ± 1.49 and 32.16 ± 1.14 by during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The ESR (mm/hr) was 5.50 ± 0.32 preoperatively. It was 5.00 ± 0.26, 4.12 ± 0.22, 3.25 ± 0.41, 3.33 ± 0.28 and 2.33 ± 0.18 during the immediate, second, fourth, sixth postoperative and eighth weeks respectively.

The WBC counts (10^3 /cu.mm) was 10.86 ± 0.46 preoperatively. It was 10.53 ± 0.57, 9.31 ± 0.31, 9.46 ± 0.28, 8.68 ± 0.31 and 9.08 ± 0.33 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The mean neutrophil count (%) was 67.75 ± 1.39 preoperatively. It was 67.25 ± 1.06, 65.62 ± 0.92, 63.62 ± 1.19, 65.83 ± 1.27 and 67.00 ± 0.92 during the immediate, second, fourth and sixth postoperative weeks respectively.

The mean lymphocyte count (%) was 29.75 ± 1.47 preoperatively. It was 31.12 ± 1.28, 32.62 ± 1.36, 34.12 ± 1.59, 33.16 ± 1.08 and 31.33 ± 0.93 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The mean monocyte count (%) was 0.88 ± 0.40 preoperatively. It was 1.12 ± 0.39, 1.37 ± 0.46, 2.00 ± 0.50, 0.85 ± 0.42 and 1.16 ± 0.41 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

Eosinophils were observed in all cases except Case Nos. 4 and 7. Eosinophils were observed during fourth week (one percent) and eighth week (two percent) in Case No. 1. Also during the same period the eosinophils observed was one percent in Case No.8. Eosinophils were observed only in immediate postoperative observation in Case No.2 (one percent) and Case No. 3 (two percent) respectively. Preoperatively eosinophils were observed only in Case No. 5 (two percent). Until second postoperative week, one percent eosinophils was observed in Case No .6 and not noticed in subsequent postoperative observation. The observation was within the normal range.

4.9. SERUM BIOCHEMICAL EVALUATION

The serum biochemical parameters recorded were represented in table 8.

The serum calcium concentration (mg/dl) was 11.25 ± 0.36 during the preoperative evaluation. It was 10.75 ± 0.45, 10.00 ± 0.26, 9.37 ± 0.41, 10.16 ± 0.34 and 9.83 ± 0.26 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The serum phosphorus concentration (mg/dl) was 3.62 ± 0.18 during the preoperative evaluation. It was 3.37 ± 0.26, 2.87 ± 0.29, 2.12 ± 0.29, 2.83 ± 0.34 and 2.83 ± 0.34 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

The serum alkaline phosphatase concentration (IU/l) was 151.25 ± 6.04 during the preoperative evaluation. It was 176.50 ± 14.70, 177.50 ± 10.41, 103.62 ± 8.25, 82.50 ± 8.62 and 73.83 ± 9.67 during the immediate, second, fourth, sixth and eighth postoperative weeks respectively.

4.10 MANAGEMENT OF COMPLICATIONS

The various complications observed during the study period were angular deformity, pin loosening, pin tract drainage, quadriceps muscle contracture, patellar ligament calcification, stifle stiffness and breakage of acrylic connecting bar.

4.10.1 Angular deformity

Mild angulation between the fracture fragments was observed in immediate postoperative radiograph of Case No. 7, as the selected intramedullary pin was not appropriate to fill the medullary canal completely. However, this was found corrected spontaneously in the subsequent radiographs and no corrective measures were employed.

4.10.2 Pin loosening

Pin loosening was noticed during the postoperative observation period in Case No. 2 and 6 where acrylic and stainless connecting bar were used respectively. In Case No. 2, by fourth postoperative week pin loosening was observed in the distal site which was subsequently removed by the animal and it was reapplied later. Inspite of this there was appreciable fracture healing both clinically and radiographically.

Case No. 6 was recumbent on the implant side by second postoperative week due to spondylosis, which caused pin loosening. As the primary cause of recumbancy was spondylosis, no measures were found suitable to counteract the pin loosening. Instead the implants were removed by sixth week as there was palpable clinical union, although radiographic union was not complete even by sixth week.

4.10.3 Pin tract drainage

Pin tract drainage was noticed in Case Nos. 1, 2, 3, 5, 6 and 8. The pin tract entries were cleaned with moist cotton and povidone iodine was infused through the pin tracts where there was serous discharge from the tracts. This was found to be effective in controlling pin tract drainage in Case Nos. 1, 3, 5, and 8. But in Case Nos. 2 and 6, the drainage persisted until implant removal. In Case No. 2, the pin tract drainage was solely because of mutilation, yet it did not interfere with fracture healing and functional limb usage.

4.10.4. Breakage of acrylic bar

There was severe mutilation in Case No. 2 that led to breakage of acrylic column by second postoperative day itself. This was found between the intramedullary pin and first fixation pin. Broken acrylic column was joined together by adhesive tape. Again by second postoperative week, the animal had removed the acrylic column along with distal fixation pin (Plate 13). Then a new acrylic column was applied along with the distal pin. Again by eighth postoperative week, there was complete removal of acrylic column by the animal (Plate 14). Although the implant mutilation was observed through out the observation period, the radiographic and clinical union of the fracture site was good.

TABLE 1. ANAMNESIS OF THE CASES STUDIED

CASE NO.	BREED	AGE	SEX	BODY WEIGHT (KG)	EXCITING CAUSE OF FRACTURE	LIMB AFFECTED	DURATION OF ILLNESS
1	German Shepherd Dog	5 years	Male	31	Automobile accident	Left forelimb	2 days
2	Spitz	3 years	Male	13	Automobile accident	Right hind limb	4 days
3	German Shepherd Dog	10 months	Male	20	Automobile accident	Left hind limb	4 weeks
4	German Shepherd Dog	2 months	Female	4.5	Fall from height	Left hind limb	2 days
5	Lhasha Apso	11 ½ years	Male	15	Automobile accident	Right hind limb	4 days
6	German Shepherd Dog	6 years	Female	32	Automobile accident	Right hind limb	2 days
7	Great Dane	3½ months	Female	15	Fall from height	Left hind limb	1 week
8	Great Dane	11½ months	Female	20	Automobile accident	Left hind limb	1 week

TABLE 2. RADIOGRAPHIC APPEARANCE OF FRACTURES STUDIED

CASE NO.	BONE INVOLVED	LOCATION	TYPE OF FRACTURE
1	Humerus	Distal third	Comminuted fracture with a butterfly fragment
2	Femur	Distal third	Simple oblique overriding fracture with a butterfly fragment
3	Tibia and fibula	Middle third	Simple oblique overriding fracture of tibia and fibula with mal-union
4	Femur	Middle third	Simple oblique over riding fracture
5	Femur	Proximal third	Simple complete transverse fracture
6	Femur	Middle third	Simple complete oblique over riding fracture
7	Femur	Middle third	Simple short oblique fracture
8	Femur	Proximal third	Simple complete transverse fracture

TABLE 3. CONNECTING BAR AND TIE-IN CONFIGURATION ADOPTED IN CASES STUDIED

CASE NO.	BODY WEIGHT (KG)	BONE INVOLVED	AGE	CONNECTING BAR
1	31	Humerus	5 years	Stainless steel connecting bar with out tie-in configuration
2	13	Femur	3 years	Acrylic connecting bar with tie-in configuration
3	20	Tibia and fibula	10 months	Stainless steel connecting bar with tie-in configuration
4	4.5	Femur	2 months	Acrylic connecting bar with tie-in configuration
5	15	Femur	11 ½ years	Acrylic connecting bar with tie-in configuration
6	32	Femur	6 years	Stainless steel connecting bar with out tie-in configuration
7	15	Femur	3 ½ years	Acrylic connecting bar with tie-in configuration
8	20	Femur	1 years	Stainless steel connecting bar with out tie-in configuration

TABLE 4. EVALUATION OF FUNCTIONAL LIMB USAGE

Case No.	Preoperative Period	Postoperative period				
		II week	IV week	VI week	VIII week	Time taken to resume normal gait
1	10	10	8	7	6	After implant removal
2	9	9	6	4	2	VI week
3	4	4	8	*	*	*
4	9	9	2	2	2	Tenth day
5	10	10	4	4	4	Led to non union
6	10	10	8	10	*	
7	9	9	2	1	1	Tenth day
8	9	9	2	*	1	II week

0 : Sound
1 : Occasionally shifts weight
2 : Mild lameness at a slow trot, none while walking
3 : Mild lameness while walking
4 : Obvious lameness while walking, but places the foot when standing
5 : Degrees of severity
6 : Degrees of severity
7 : Degrees of severity
8 : Degrees of severity
9 : Places toe when standing, carries limb when trotting
10 : Unable to put the foot on the ground

* : Not available

TABLE 5. PHYSIOLOGICAL PARAMETERS (MEAN ± SE)

n=8

PARAMETERS	DAY OF OBSERVATION					
	Pre operative	Post operative	II week	IV week	VI week	VIII week
Respiration rate (per minute)	32.37 ± 1.60	30.25± 1.43	31.62 ± 1.16	33.75 ± 2.31	32.83 ± 1.61	30.00 ± 0.89
Pulse rate (per minute)	99.12 ± 3.20	94.25± 2.05	95.00 ± 3.40	95.75 ± 1.38	97.66 ± 1.63	99.33 ± 1.15
Rectal temperature (^{0}C)	39.16 ± 0.26	38.57 ± 0.10	38.80 ± 0.21	39.00 ± 0.14	38.83 ± 0.25	38.78 ± 0.18

TABLE 6. EVALUATION OF IMPLANTS

CASE NO.	OBSERVATION PERIOD	APPARATUS STABILITY	PATIENT ACCEPTANCE	MUTILATION	PIN TRACT DRAINAGE
1	II week	Intact	S	-	+
	IV week	Intact	S	-	+
	VI week	Intact	S	-	-
	VIII week	Intact	S	-	-
2	II week	Breakage of acrylic bar	NS	+	+
	IV week	Pin loosening	NS	+	+
	VI week	Intact	NS	+	+
	VIII week	Breakage of acrylic bar	NS	+	+
3	II week	Intact	S	-	+
	IV week	Intact	S	-	+
4	II week	Intact	S	-	-
	IV week	Intact	S	-	-
	VI week	Intact	S	-	-
5	II week	Intact	S	-	+
	IV week	Intact	S	-	-
	VI week	Intact	S	-	-
	VIII week	Intact	S	-	-
6	II week	Pin loosening	NS	-	+
	IV week	Pin loosening	NS	-	+
	VI week	Pin loosening	NS	-	++
7	II week	Intact	S	-	-
	IV week	Intact	S	-	-
	VI week	Intact	S	-	-
	VIII week	Intact	S	+	-
8	II week	Intact	S	-	+
	IV week	Intact	S	+	+
	VI week	Intact	S	-	-
	VIII week	Intact	S	-	-

S- Satisfactory
NS-Not Satisfactory (serous discharge present)

- Absent
++ Purulent discharge
+ Present

Table 7. RADIOGRAPHIC EVALUATION OF FRACTURES UNDER STUDY DURING OBSERVATION PERIOD

C. No	ALIGNMENT					APPOSITION				ANGULATION					ACTIVITY(CALLUS)										ARCHITECTURE									
															PERIOSTEAL					ENDOSTEAL					PERIOSTEAL REACTION					OSTEOLYSIS				
	PO	II	IV	VI	VIII	PO	IV	VI	VIII	PO	II	IV	VI	VIII	PO	II	IV	VI	VIII	PO	II	IV	VI	VIII	PO	II	IV	VI	VIII	PO	II	IV	VI	VIII
1	+	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-
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8	+	+	+	*	+	+	+	*	+	-	-	-	*	-	-	+	+	*	+	-	+	+	*	+	-	+	-	*	-	-	-	-	*	+

PO - Immediate postoperative
II - Second week
IV - Fourth week
VI - Sixth week
VIII - Eighth week
\- - Absent
\+ - Present
* - Not available

TABLE 8. HAEMATOLOGICAL AND SERUM BIOCHEMICAL EVALUATION (MEAN ± SE)

n=8

PARAMETERS		DAY OF OBSERVATION					
		Preoperative	Postoperative	II week	IV week	VI week	VIII week
Haemoglobin concentration (g/dl)		12.75 ± 0.59	11.87 ± 0.51	11.00 ± 0.46**	11.25 ± 0.31	12.66 ± 0.28	12.83 ± 0.26
VPRC (%)		36.37 ± 1.23	37.00 ± 1.37	33.87 ± 1.36	36.50 ± 0.56	35.83 ± 1.49	32.16 ± 1.14
ESR (mm/hr)		5.50 ± 0.32	5.00 ± 0.26*	4.12 ± 0.22**	3.25 ± 0.41**	3.33 ± 0.28**	2.33 ± 0.18**
Total leucocyte count (per 10^3 /cu.mm)		10.86 ± 0.46	10.53 ± 0.57	9.31 ± 0.31*	9.46 ± 0.28**	8.68 ± 0.31*	9.08 ± 0.33*
Differential count	N%	67.75 ± 1.39	67.25 ± 1.06	65.62 ± 0.92	63.62 ± 1.19*	65.83 ± 1.27	67.00 ± 0.92
	L%	29.75 ± 1.47	31.12 ± 1.28	32.62 ± 1.36	34.12 ± 1.59*	33.16 ± 1.08	31.33 ± 0.93
	M%	0.88 ± 0.40	1.12 ± 0.39	1.37 ± 0.46	2.00 ± 0.50*	0.85 ± 0.42	1.16 ± 0.41
Serum calcium (mg/dl)		11.25 ± 0.36	10.75 ± 0.45*	10.00 ± 0.26**	9.37 ± 0.41*	10.16 ± 0.34	9.83 ± 0.26*
Serum phosphorus (mg/dl)		3.62 ± 0.18	3.37 ± 0.26	2.87 ± 0.29*	2.12 ± 0.29*	2.83 ± 0.34	2.83 ± 0.34
Serum ALP (IU/l)		151.25 ± 6.04	176.50 ± 14.70*	177.50 ± 10.41*	103.62 ± 8.25**	82.50 ± 8.62**	73.83 ± 9.67**

*P< 0.05 **P<0.01

Plate 11. Functional limb usage evaluation (Case No.2)

a. Limb carriage - before operation

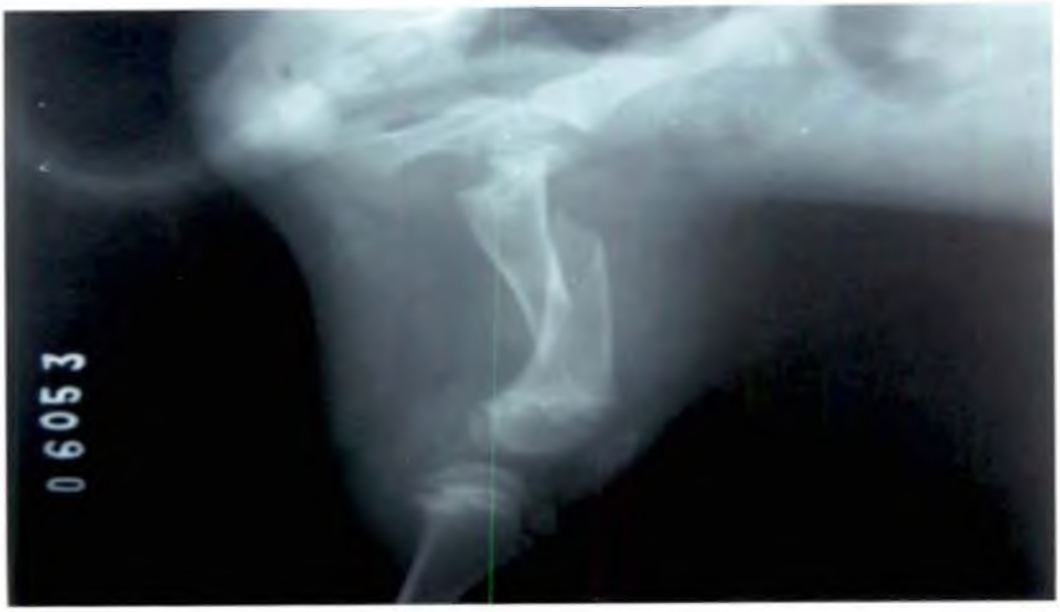
b . Weight bearing at second postoperative week

c. Weight bearing at fourth postoperative week

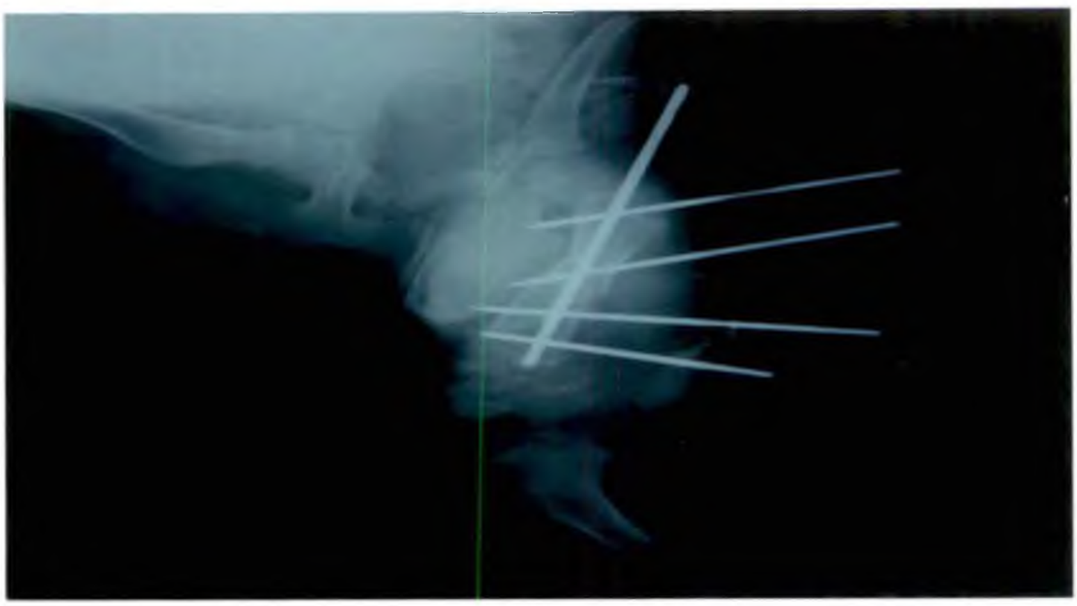
d. Weight bearing at eighth postoperative week

e. Weight bearing at tenth postoperative week

Plate 12. Radiographical evaluation (Case No. 4)

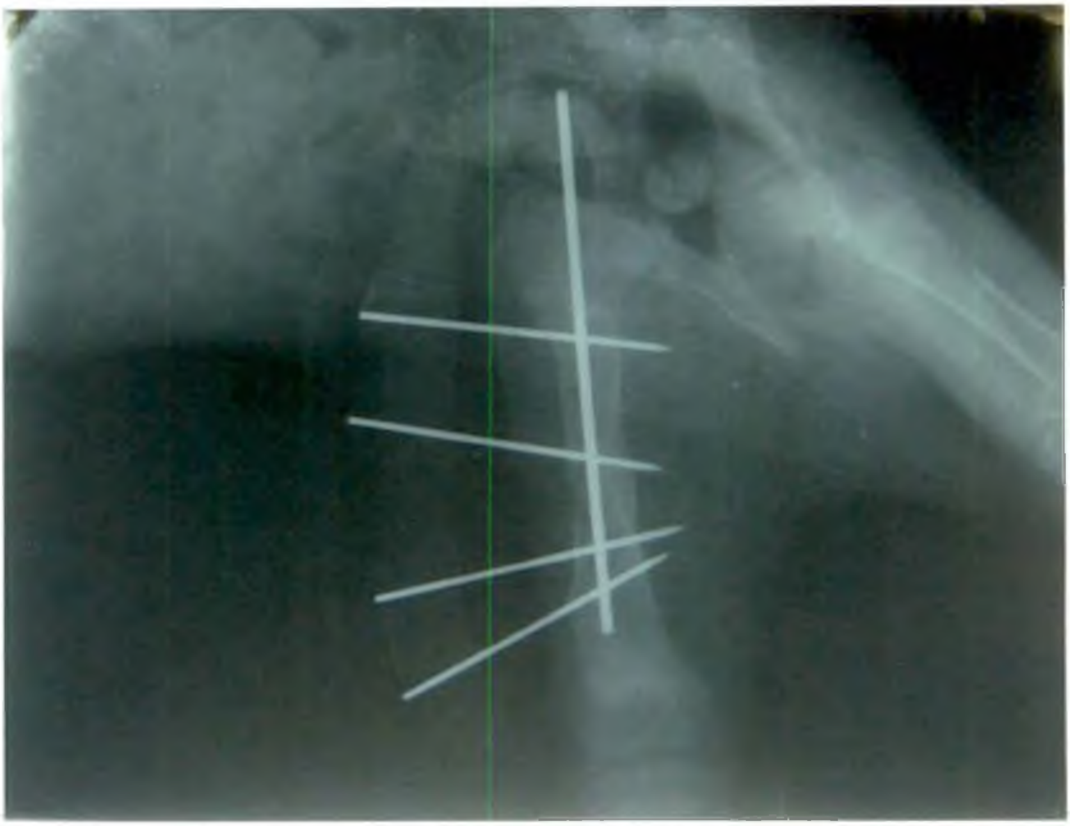


a. Preoperative appearance - Simple obllique overriding fracture at middle third of femur

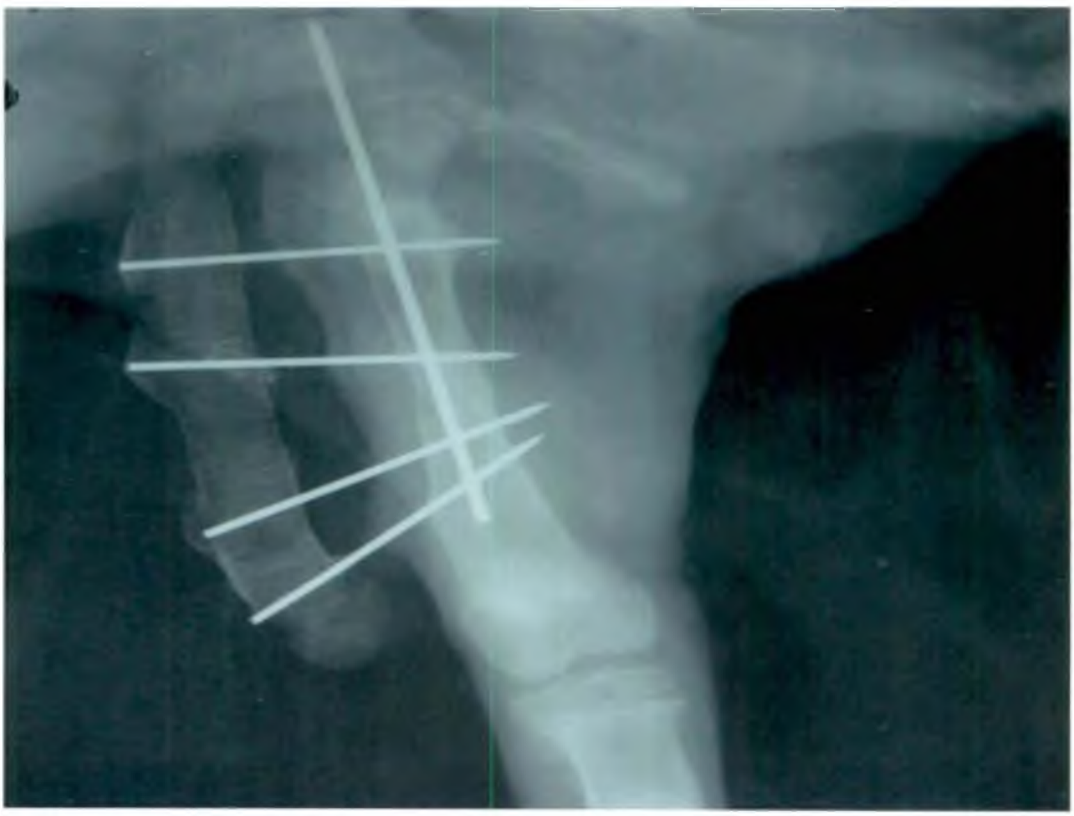


b . Immediate postoperative week appearance - Fragments in correct alignment and apposition

c . Second postoperative week appearance - Thin callus bridging fracture



d . Fourth postoperative week appearance - Good apposition between the fragments with visible callus formation



e . Sixth postoperative week appearance -Thick callus filling the fracture gap

Plate 13. Breakage of acrylic column along with complete removal of distal fixation pin by second week (Case No. 2)

Plate 14. Complete self mutilation of implants with a large wound cavity at the exit point of intramedullary pin by eighth week (Case No. 2)

Plate 15. Obvious evidence of radial nerve paralysis following humerus fracture on the day of presentation (Case No. 1)

Plate 16. Evidence of quadriceps muscle contracture at fourth postoperative week (Case No.4)

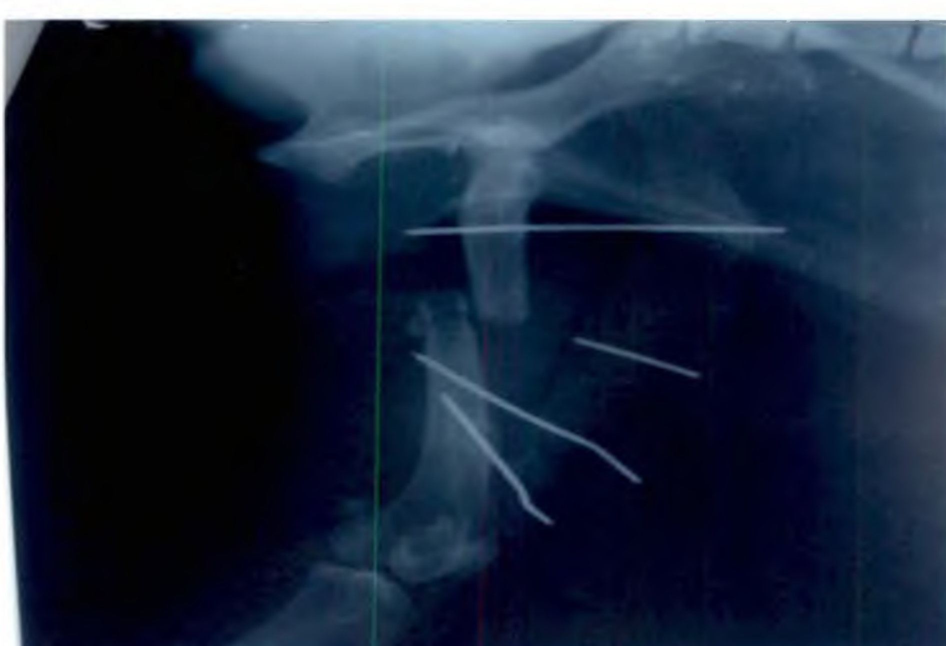


Plate 17. Nonunion observed at eighth postoperative week (Case No.5)

Discussion

5. DISCUSSION

Among the long bones, femur and humerus are the two abaxially placed bones present held close to the body. So immobilizing these bones with external coaptation technique would result in fracture instability and failure. The present study was intended to manage the fracture of long bones, especially femur using external skeletal fixation in combination with intramedullary pinning, where the rotational instability could be effectively controlled. In this study, both the stainless steel and acrylic connecting bars were used for the treatment of long bones.

5.1 SELECTION OF CASES

The study was conducted in eight clinical cases of long bones, especially femur in dogs presented to the Surgery Units of Veterinary Hospitals, at Mannuthy and Kokkalai, College of Veterinary and Animal Sciences, Mannuthy, during the period from April 2005 to June 2006. The selected patients were subjected to treatment with external skeletal fixation in combination with intramedullary pinning. Acrylic connecting bars were used in those animals which were below 15 kg body weight and stainless steel connecting bars were used in those animals above 15 kg body weight. During the follow up period, animals were subjected to clinical, radiological, haematological and serum biochemical evaluation, both preoperatively and postoperatively and observations were recorded fortnightly, upto eight weeks.

5.2 ANAMNESIS

Number of animals selected for the study belonging to each breed was German Shepherd Dog (4), Great Dane (2), Spitz (1) and Lhasa Apso (1).

Balagopalan *et al.* (1995) reported highest incidences of fracture of long bones among Alsatian followed by in Doberman Pinscher, Non Descript and then in Spitz. The animals weighed between four and a half to thirty two kilogram body weights. The age group of the animals ranged from two months to eleven and a half years with 50% of the animals presented were below one year of age. Survey conducted by Aithal *et al.* (1999) revealed highest incidence of fracture in the age group of 1 to 3 years and also reported higher incidence of fractures in males than in females. Among those animals affected, four were males (50%) and the remaining four were females (50%).

5.3 TYPES OF FRACTURES

Of the cases selected for study, six cases were of femoral fracture (75%) and one case each of humerus (12.5%) and tibia and fibula (12.5%). Five of the fractures were oblique (62.5%) which included a malunion of the tibia and fibula, two transverse (25%) and one comminuted fracture with a butterfly fragment (12.5%). In the survey report of Singh *et al.* (1983) revealed that femoral fracture had higher incidence among dogs followed by fracture of tibia, radius and ulna, and that of humerus.

5.4 SELECTION OF MATERIALS

5.4.1 Fixation pins

Smooth pins (K wires) were used in all cases except in Case No. 3 where Schanz screws were used. Anderson *et al.* (1993) recommended threaded pins in all but simplest of fracture because of their increased holding capacity and added that the functional limb usage returned to normal only slowly in those animals where nonthreaded pins were used. According to Anderson *et al.* (1997), negative profile pins had a greater tendency to break at the thread-nonthread interface. But pin breakage did not occur in any of the cases.

Pins were selected from the preoperative radiograph such that it occupied 20-30% of the diameter of the bone. Rochat (2001) mentioned that the pins selected for fixation must be 20% of the bone diameter and recommended that the selected pins should be drilled about 1 cm from the fracture site to 1 cm from the adjacent joints. Carmichael (1991) opined that the pin selected should occupy not more than one-third diameter of the bone.

5.4.2 Acrylic column moulding tube

The one centimetre diameter flexible pipe was used effectively as a mould for the acrylic. This was used in Case Nos. 2, 4, 5 and 7 where the body weights of these animals were less than 15 kg. Julie (2005) suggested the use of acrylic external fixator for the immobilization of fractures of long bones in animals of less than 15 kg body weight and provided early return of functional limb usage. According to Toal and Mitchell (2002) the usage of acrylic external skeletal fixation has no advantage in dogs that weigh more than 10 kg.

Use of acrylic as connecting bar was cost effective and does not need for additional components like stainless steel clamps and bars. This was supported by Williams *et al.* (1997), Chandy (2000), Shahar (2000) and Julie (2005).

5.5 EVALUATION OF THE TECHNIQUE

5.5.1 Anaesthetic protocol

The surgery was done under general anaesthesia. Atropine and xylaxine was used as preanaesthetic and general anaesthesia was induced and maintained with xylaxine, ketamine and diazepam combination. The usage of these anaesthetic protocols was found satisfactory without any complication. Julie (2005) premedicated dogs with atropine sulphate followed by xylazine hydrochloride and induced general anaesthesia with ketamine intramuscularly and general anaesthesia was mainained with xylazine-ketamine mixture (equal volumes) and diazepam intravenously.

5.5.2 Reduction and retention of fracture fragments

Application of intramedullary pin along with Type IA ESF necessitated the open approach in all the cases under study. The surgical incision was made on the cranio medial aspect of the long bones like femur and humerus.

5.5.3 Insertion of fixation pins

In all cases under study, the pins were inserted in safe corridors and no complication occurred due to injury of vital anatomical structures like blood vessels, nerves, muscles and tendons. Butterworth (1993) revealed that humerus and femur have no real safe corridors as they are surrounded by muscles and recommended a guide for most appropriate location for a type I (unilateral, uniplanar) fixator for various long bones. Both humerus and femur were approached through lateral aspect, where as the approach for proximal radius is cranio-lateral and that for distal radius is cranio-medial. Tibia is approached medially.

Two pins were placed in each fragment in all cases except in Case Nos. 1 and 2. In Case Nos. 1 and 2, the fracture site was located at distal diaphysis of humerus and femur respectively. In Case No. 1, three pins were driven in the proximal fragment and one pin in the distal fragment and in Case No. 2, only one pin was drilled into the distal fragment and two pin in the proximal fragment. Drilling one pin alone in the distal fragment did not interfere with fracture healing and subsequent limb usage. Slow speed electrical bone drill was used to drive the pins. VanEe and Geasling (1992) recommended a minimum of two fixation pins for each major fragment to be stabilized and recommended the ideal speed for pin insertion as 150-400 rpm in small pulses.

Pins were drilled almost at an angle of 70 degree from the long axis of the bone in Case Nos. 1, 3, 6 and 8 and parallel in Case Nos. 2, 4, 5 and 7. This difference does not make any variation in fracture healing mechanism and the functional limb usage was satisfactory. But pin loosening was observed in Case Nos. 2 and 6, where the cause for pin loosening was self mutilation. Boothe and Tangner (1983) revealed that the pins inserted in the proximal and distal fragment should form a 45 degree angle to each other and each pins should be inserted at a 65 degree angle to the bone. Straw (1984) and Nunamaker (1985) reported that premature pin loosening might occur if the pins are placed parallel to each other and Rochat (2001) observed no premature pin loosening as a result of pins inserted parallel to each other. In this present study also there was no premature pin loosening because of pins inserted parallel to each other.

Pins were inserted atleast one centimeter away from the fracture site. Rochat (2001) mentioned that the pins selected should be drilled about one cm away from the fracture site and one cm away from adjacent joints. In Case No. 5, the second pin was found inserted at the fracture site and by sixth week it was removed to stimulate callus formation. But, inspite removal of fixation pin from the fracture site, no further callus formation was observed even by eighth week and resulted in non-union. In Case No. 2, the distal pin was found inserted at the fracture site. However it does not interfere with callus formation. This was supported by Johnson *et al.* (1989) who observed that even if the fixation pins were inserted within or very close to a fracture line, fracture healing was not adversely affected.

5.5.4 Intramedullary pinning

Intramedullary pin was selected from the preoperative radiograph such that it occupied 70% of the medullary cavity at the isthmus. According to Anderson and Aron (1998) an intramedullary pin should not be greater than half the diameter of the isthmus of the bone. Vasseur *et al.* (1984) revealed the usage of pin that occupied 75% of the medullary cavity. However Langley-Hobbs *et al.* (1996) recommended the pin selected should occupy 50% of the medullary cavity. In Case No. 7, the pin selection was not appropriate and a smaller than required size pin was used for intramedullary pinning. This resulted in mild angulation at the fracture site.

Intramedullary pin was placed in retrograde fashion without any complication. Lorinson *et al.* (1997) recommended deep placement of pin into the distal femoral epiphysis (DFE) and patella thickness could be used to estimate the safe depth of pin penetration. Although the pin was not correctly placed into the distal femoral epiphysis in all cases except Case No. 7, the stability attained was satisfactory.

5.5.5 Stainless steel external skeletal fixation

Pins were selected from the preoperative radiograph such that it occupied 20-30% of the diameter of the bone. Rochat (2001) reported that the pins selected for fixation must be 20% of the bone diameter. According to Carmichael (1991) the pin selected should occupy not more than one-third diameter of the bone.

Stainless steel external skeletal fixation was used in Case Nos. 1, 3, 6 and 8 and the pins were drilled approximately at an angle of 70 degree from the long axis of the bone. Boothe and Tangner (1983) recommended that the pins inserted in the proximal and distal fragment should form a 45 degree angle to each other and each pins should be inserted at a 65 degree angle to the bone. This was supported by Brinker *et al.* (1985) and McPherron (1992).

Connecting bars and clamps were connected as mentioned by Harari *et al.* (1998) and Rochat (2001). Its usage was satisfactory in all cases except Case No. 6, where the animal had spondylosis and was constantly lying down on the implant side. This predisposed to bone splintage by second postoperative week.

5.5.6 Acrylic connecting bar

Acrylic as connecting bar was used in Case Nos. 2, 4, 5 and 7, where the body weight of these animals where less than 15 kg. Breakage of acrylic column occurred in Case No. 2 due to self mutilation. However it does not interfere with fracture healing and subsequent limb usage. Julie (2005) recommended acrylic external fixator in animals that weigh less than 15 kg which provided early return of functional limb usage and observed breakage of acrylic column when used for immobilization of femoral fracture.

The preparation and application of acrylic as connecting bar was satisfactory. As mentioned by Ross and Matthiesen (1993) a distance of one centimetre was maintained between the skin and acrylic column that provided enough space for postoperative swelling. This does not produce any difficulty in cleaning the skin-bar interface or caused any thermal necrosis of tissues of any dogs. As reported by Nunamaker (1985) and VanEe and Geasling (1992) the stability of the fixator could be increased by reducing the distance between the external frame and limb.

Ross and Matthiesen (1993) reported the breakage of acrylic column and in the present study breakage of acrylic column was observed only in Case No. 2 which was due to self mutilation.

5.5.7 Postoperative care

For successful postoperative recovery, Rochat and Payne (1993) opined that good postoperative care and owner's compliance were necessary.

Discharge from the pin entry points and the suture lines were cleaned regularly with 5% povidone iodine solution for the first one week. When discharge from the pin tract stopped, cleaning was done only when needed. Butterworth (1993) mentioned that light discharge from the pin tract was common that seals the pin-skin interface by forming a crust and suggested to avoid bathing the pin-skin junction as it would create a soup of commensel bacteria that increases the likelihood of a pin tract infection. VanEe and Geasling (1992) suggested that it was better not to remove the scab formed at the pin exit and entry points so as to avoid entry of infection.

Soft padded bandage was applied around the external fixator as recommended by Anderson *et al.* (1993) and was changed depending on the amount of pin tract drainage and soilage.

5.5.8 Removal of the implants

Implants were removed based on the radiographic union except in Case No. 6 where the implants were removed based on the clinical union. According to Butterworth (1993) clinical union generally precedes the radiographic union and recommended the removal of external fixator based on the clinical union. Ozsoy and Altunatmaz (2003) mentioned that fixator was removed based on the callus formation that was evaluated regularly with postoperative radiographs.

Implants were removed under mild sedation with xylazine in Case Nos. 1, 4, 5, 7 and 8 after atropine premedication. Mild sedation was recommended by VanEe and Geasling (1992) and was found to be sufficient enough for external fixator removal.

Pins were removed satisfactorily as mentioned by Harari *et al.* (1998) with a Jacobs hand chuck. Acrylic fixation pins were removed as mentioned by Okrasinski *et al.* (1991) and the pieces still attached to the fixation pin were used as convenient handles for easy removal.

Both the external fixtor and the intramedullary pins were removed on an average of eight weeks and there was wide variation in the fixator removal reported by many authors. According to Johnson *et al.* (1989) and Johnson *et al.* (1996) the mean time for fixation removal was at tenth week and 14.7 weeks respectively.

5.6 PATIENT EVALUATION

Preoperative evaluation of all the parameters ie., clinical, physiological, haematological and serum biochemical were useful for comparing and evaluating the postoperative observations.

5.6.1 General clinical condition

5.6.2 Functional limb usage

As noticed by Ozsoy and Altunatmaz (2003) early limb usage was noticed by third postoperative day in Case Nos. 2, 4, 6, and 7, where the animals were seen to make slight ground contact with the leg. Rochat (2001) opined that rigid fixation was required to avoid poor limb function and the early limb usage emphasized the stability of the fixator.

Poor limb usage was noticed in Case No. 1 as the result of radial nerve paralysis. To avoid radial nerve complication, Langley-Hobbs *et al.* (1997) made attempts to avoid placing the pin in the region of radial nerve. But preoperatively the animal was presented with radial nerve paralysis and showed satisfactory improvement in functional limb usage after implant removal.

Case No. 3 was not bearing weight on the ground and the animal succumbed to death by fourth postoperative week because of parvoviral enteritis. Also Case No. 6 was bearing weight until second postoperative week and later on the animal went recumbent over the implant as a result of spondylosis.

There was obvious lameness noticed throughout the observation period in Case No. 5. This animal showed no callus formation even by eighth week of presentation and resulted in non-union. Vaughan (1975) reported inadequate immobilization is the primary cause of most of the delayed union and nonunions. Although there was good immobilization noticed from the preoperative radiograph, there was complete absence of callus even by eighth postoperative week. Langley-Hobbs (2003) differentiated nonunion fractures into biologically active and inactive forms and added that most common biologically inactive fracture falls under atrophic category. Case No. 5 also falls under this category with no evidence of bone activity. Anderson *et al.* (1993) and Egger (1983) mentioned pin tract sepsis and premature pin loosening as the common complication associated with linear ESF, which ultimately resulted in delayed union or nonunion. However in this case pin tract sepsis and premature pin loosening were negligible and were not the primary cause for fracture nonunion. According to Rochat and Payne (1993) and Piermattei and Flo (1997) fracture heals at different rates in animals of different ages. This animal being older (11 ½ yrs) might be the reason for no callus formation that resulted in nonunion.

Quadriceps muscle contracture was noticed in Case Nos. 4 and 8 with inability to flex the stifle joint. Both the dogs were young growing animals with Case Nos. 1 and Case No. 2 presented at 2 and 11 ½ months respectively. According to Dewey *et al.* (1994) high rate of complication like delayed union and quadriceps contracture or 'tie-down' occur commonly following the combined use of a type IA unilateral fixator and an intramedullary pin in the repair of femoral fracture. Also Egger *et al.* (1986) observed quadriceps contracture and stifle extension with the use of type I double connecting bar configuration on long bone fractures in dogs. Stigen (1999) recorded quadriceps muscle contracture in young growing animals that commonly followed the immobilization of distal femur fracture.

Vaughan (1975) noted that the limitation in flexion of stifle was obviously because of quadriceps muscle contracture and also due to simple tissue adhesions around the stifle and disuse of muscle function. In this present study also there was stifle extention noticed in both the animal. In Case No. 8 calcification of patellar ligament could be appreciated form the eighth postoperative radiograph.

5.6.3 Peripheral lymph nodes

There was slight increase in the size of popliteal lymph nodes in Case Nos. 7 and 8 during the sixth and fourth postoperative week respectively. Blood examination revealed no parasites. This slight increase in peripheral lymph nodes may be due to the inflammatory process in wound healing mechanism. This was also supported by Chandy (2000) and Julie (2005).

5.6.4 Pain at the fracture site

Preoperatively all the dogs exhibited pain on palpation at the fracture site. Case Nos. 1 and 6 exhibited mild pain through out the observation period. This might be because of severe impact of the automobile accident and indicated the degree of instability also. Absence of pain in other animals from second postoperative week onwards indicated stable fixation. This was supported by Chandy (2000) and Julie (2005)

5.6.5 Proprioceptive reflex

Case No. 1 showed the symptoms of radial nerve paralysis at the time of presentation itself. It had proprioceptive reflex deficit throughout the observation period. However there was slight improvement in reflex after the implant removal.

Case Nos. 3, 5 and 6 which showed sluggish reflex which may be due to postoperative inflammatory reaction and oedema compressing the nerve. This was mentioned by Julie (2005).

5.6.6 Physiological parameters

The physiological parameters observed were within the normal range. This proved that there was no systemic reaction produced as a result of fracture incidence and the immobilization procedure employed.

5.7 IMPLANT EVALUATION

5.7.1 Apparatus stability

For early fracture healing the stability of the apparatus is essential. External fixator was stable in all animals throughout the observation period except Case No. 2 where breakage of acrylic column and pin loosening occurred mainly because of self mutilation. According to Egger (1983) the weak component of the single connecting bar configuration was the connecting bar itself particularly at the fracture gap. In this case also the acrylic column was broken between the distal two pins i.e., exactly at the level of fracture site.

Case No. 6 was recumbent on the implant side after second postoperative week. Femur being strongly surrounded by muscles, there could be stronger muscle pull that resulted in bone splintering. This caused pin loosening and bending.

5.7.2 Patient acceptance

Implant usage was found to be satisfactory with no case of tissue reaction noticed during the entire observation period.

5.7.3 Mutilation

Out of eight animals, Case Nos. 2 exhibited severe mutilation, where the acrylic connecting column was broken on the second postoperative day itself. It was broken between the proximal fixation pin and the intramedullary pin.

Usually the mutilation occurred because of severe itching, irritation or pain. To prevent the mutilation Anderson *et al.* (1993) recommended soft padded bandages around the external skeletal fixator. As suggested by Julie (2005) mutilation might be due to pain of surgery that gets subsided within few days. But continuous mutilation of the implant was observed in Case No. 2. When applying an external fixator VanEe and Geasling (1992) mentioned that the skin was to be positioned in the manner it would be found when the wound was closed otherwise necrosis would follow if the skin was under tension. This could also be a reason for mutilation but the innate nature of some animals to mutilate on bandages, casts or any other material found on their body should also be considered. The possibility of mutilating the fixator when applied to a fractured limb was described by Hatt (2003).

5.7.4 Pin tract drainage

According to Bennett *et al.* (1987) usage of external skeletal fixation in the femur requires penetration of large muscle masses that may predispose to pin tract drainage as a result of increased mobility between the pin and soft tissues

Mild pin tract drainage was noticed in Case Nos. 3, 4, 5 and 7. In Case No. 1 and 8 the discharge was mainly due to maggot wound infestation noticed during fourth week of presentation. As observed by VanEe and Geasling (1992) serosanginous discharge could be noticed during the immediate postoperative period which leads to scab formation at the pin entry and exit points. Egger *et al.* (1986) opined that pin tract drainage could result from loose pins or tension of the soft tissues against pins. Due to self mutilation, the distal transfixaion pin got loosened and there was mild serous discharge noticed from the distal tract. As opined by VanEe and Geasling (1992) excessive drainage in Case No. 6 might be due to excessive muscle mass trying to move across the pin during ambulation.

5.8 RADIOGRAPHIC EVALUATION

5.8.1 Fracture reduction and apparatus stability

The stability of the apparatus was good through out the observation period except in Case No. 2 where the acrylic column was broken by self mutilation. Later the acrylic column was reapplied and showed good improvement in fracture healing and subsequent functional limb usage. The proper apposition between the fracture fragments were well maintained throughout the observation period with progressive bridging of fragments with callus.

From the immediate postoperative radiograph, the fracture fragments were in good apposition in most of the cases except Case No. 1 as the fracture site was noticed at the distal diaphysis. VanEe and Geasling (1992) recommended the use of external skeletal fixation with intramedullary pins and cerclage wires. In this case also cerclage wiring was combined along with the present study to keep the butterfly fragment intact.

Mild angulation between the fracture fragments noticed in Case No. 7 but appeared insignificant clinically. Finally when the fracture gap got filled with sufficient callus, the straightness of the bone was restored to normal. According to Johnson *et al.* (1989) even when angular deformities were visually evident, the effect on the functional use of the limb might be insignificant.

Although immediate postoperative radiograph in Case No. 6 showed a near perfect apposition, the bone was splintered by second postoperative week. The animal was recumbent on the implant side because of spondylosis. This might have exhibited stronger muscle pull surrounding the femur.

5.8.2 Fracture healing

Obviously the rate of fracture healing and callus formation varied with different age group of animals. Case Nos. 4, 7 and 8 being young growing animals (2 months, 3 ½ months and 11 ½ months respectively) showed rapid callus formation that necessitated the removal of implants by sixth week in Case No. 4. According to Rochat and Payne (1993) and Piermattei and Flo (1997) age of the animal should influence the choice of fracture repair because fracture heals at different rates in animals of different ages. Case No. 5 being very old showed no evidence of callus formation even by eighth postoperative week and resulted in nonunion.

In the present study the implants were removed based on the radiographical and clinical union. Gemmill (2004) mentioned that the mean time to clinical union (TCU) was 66 days for Type IA frame, 49 days for Type IA frame with an IMP.

Langley-Hobbs (2003) noted that the rate of healing in fractures treated with open reduction and internal fixation (ORIF) was lower than similar treatment by closed application of external fixator and added that fractures of upper limb bones heal more quickly than the distal limb bones because of large tissue envelope. This type of healing noticed in all the animals was with the help of both periosteal and endosteal callus formation.

According to Johnson *et al.* (1996) and Ozsoy and Altunatmaz (2003) fractures treated with external fixator healed with endosteal callus rather than periosteal callus.

Johnson *et al.* (1989) noticed periosteal reaction following external fixator application. Mild periosteal reaction was noticed in Case No. 1 and moderate in Case Nos. 3, 6 and 8. Johnson and Hulse (2002) mentioned that excessive periosteal callus was indicative of the fact that the fixation was not perfectly stable. This was observed in Case No. 2 where the implants instability was noticed as the result of self mutilation. However fracture healing and early functional limb usage was satisfactory. This periosteal reaction might be due to the sensitization of the periosteum during pin insertion.

5.8.3 Osteolysis

Mild osteolysis could be observed only in Case No. 6 from the sixth postoperative week. As described by Mathews *et al.* (1984) Osteolysis around pin tracts indicates thermal necrosis of the bone cortex. Since osteolysis was noticed only in the distal pin tract, thermal necrosis could not be attributed to it. As reported by Harari *et al.* (1998) osteolysis might have occurred because of micromovement of the pins within the bone causing bone resorption. Also the same animal was recumbent from second postoperative week which have resulted in pin loosening and bending. This might have caused osteolysis in the distal pin tract.

5.9 HAEMATOLOGICAL EVALUATION

No significant variation was noticed in most of the haematological parameters during the observation period. However, a significant decrease in the mean haemoglobin was noticed by second week. Also there was a significant decrease in ESR in the immediate postoperative observation which remained so during the following observation. The marginal variation observed in the levels of haemogram may be due to the cellular reaction to trauma during the healing process.

5.10 SERUM BIOCHEMISTRY

There was significant decrease in the serum concentration of calcium by immediate postoperative observation, which remainded until sixth postoperative week observation. A significant decrease in the serum phosphorus level was noticed during the second week of observation. During the healing period of 21 days observation, Kumar *et al.* (1992) observed a significant decline in plasma calcium and inorganic phosphorus level.

As the result of fracture healing mechanism there was significant increase in the alkaline phosphatase level by the second week of observation and significant decrease by the fourth week of observation. According to Singh *et al.* (1976) there could be significant increase in serum alkaline phosphatase level at 7 and 14 days of observation followed by a fall to normal value.

5.11 COMPLICATIONS

The common complications observed during the study period were angular deformity, pin loosening, pin tract drainage, quadriceps muscle contracture, stifle stiffness, patellar ligament calcification and breakage of acrylic connecting bar. Different complications were noticed by different authors following the application of external fixators like pin loosening (Mathews *et al.*, 1984; Piermattei and Flo, 1997; Rohact, 2001; Ozsoy and Altunatmaz, 2003), pin tract drainage (Johnson *et al.* 1989), Iatrogenic fractures (Rochat, 2001) and pin tract infection (Mathews *et al.*, 1984; Rochat, 2001; Ozsoy and Altunatmaz, 2003).

Angulation between the fracture fragments was noticed in Case No. 7. When the fracture gap was filled with callus, the straightness of the bone was restored to normal. Johnson *et al.* (1989) reported angular deformities as complication of external fixator application and added that function of the limb was not affected even by the visually evident angular deformities.

The breakage of acrylic in Case No. 2 during second postoperative week was found between the intramedullary pin and the first proximal pin. The broken acrylic column was joined together by adhesive tape. When the acrylic column was completely broken by second postoperative week, a new acrylic column was applied. Nevertheless the animal never showed any discomfort in the functional limb usage. Ross and Mattheisen (1993) have reported breakage of acrylic bar while using acrylic fixators and reported successful application of additional methylmethacrylate to bond the fractured acrylic column.

By second postoperative week pin loosening was noticed in Case No. 2, due to self mutilation. Later, the animal had removed the distal pin completely and a new pin was drilled with a new acrylic column. Okrasinski *et al.* (1991) reported that the cost of the external skeletal fixator could be prohibitive in veterinary practice and the disadvantage of external fixator could be overcome by acrylic connecting bar.

Case No. 6 was recumbent on the implant side after second postoperative week. Femur being strongly surrounded by muscles, there could be stronger muscle pull that resulted in bone splintering. This caused pin loosening and bending. Although radiographic union was not complete even by sixth week, implants were removed by sixth week as there was palpable clinical union.

According to Bennett *et al.* (1987) usage of external skeletal fixation in the femur requires penetration of large muscle masses that may predispose to pin tract drainage as a result of increased mobility between the pin and soft tissues. This was noticed in Case No. 6. The scab formed on the pin-skin junction was not disturbed and soft padded bandage was applied around the external fixator as recommended by Anderson *et al.* (1993) and was changed depending on the amount of pin tract drainage and soilage. Butterworth (1993) recommended avoiding the pin-skin junction in contrast to daily cleaning by VanEe and Geasling (1992) and Clasper *et al.* (2001) suggested that fluid accumulation around the pin-bone interface significantly contributed to spread of bacteria from superficial pin track to the medulla of the bone.

Carneiro *et al.* (2001) found that dogs treated with a 0.9% sodium chloride solution showed little purulent exudation, while dogs treated with 0.2% iodine-alcohol presented dry skin wounds with minimum serosanguineous to serous exudation. The pin tract drainage could be effectively cleaned by infusing povidone iodine and was found to be very satisfactory in all cases.

Proprioceptive reflex deficit was observed throughout the postoperative observation period in Case No. 1. Animal on the day of presentation itself had manifested the symptoms of radial nerve paralysis like dropped elbow and dragging of the limb. This might have occurred due to heavy impact of the accident. However the animal showed slight improvement after the implant removal. As mentioned by Julie (2005) Case No. 3, 5 and 6 showed sluggish reflex which may be due to postoperative inflammatory reaction and oedema compressing the nerve.

VanEe and Geasling (1992), Anderson *et al.* (1997), Harari *et al.* (1998), McLaughlin and Roush (1999) and Rochat (2001) reported thermal necrosis of bone as a complication during pin drilling. However this does not occur in any animal under the study and the technique adopted for the fracture fixation was found to be satisfactory to prevent thermal necrosis.

Quadriceps muscle contracture with inability to flex the stifle joint was noticed in Case Nos. 4 and 8. With the combined use of a type IA unilateral fixator and an intramedullary pin in the repair of femoral fracture, Dewey *et al.* (1994) reported high rate of complication like delayed union and quadriceps contracture or 'tie-down'. This was also supported by Egger *et al.* (1986). In the Case Nos. 4 and 8 quadriceps muscle contracture was noticed in young growing animals (2 and 11 ½ months respectively) as observed by Stigen (1999).

Stifle extention in Case Nos. 4 and 8 was obviously because of quadriceps muscle contracture and also due to simple tissue adhesions around the stifle and disuse of muscle function as opined by Vaughan (1975). Egger *et al.* (1986) observed quadriceps contracture and stifle extension with the use of type I double connecting bar configuration on long bone fractures in dogs.

According to Rochat and Payne (1993) and Piermattei and Flo (1997) fracture heals at different rates in animals of different ages. This might be the reason for nonunion in Case No. 5 and was classified as biologically inactive atrophic type as mentioned by Langley-Hobbs (2003).

Summary

6. SUMMARY

The present study was intended to manage the fracture of long bones, especially femur using external skeletal fixation in combination with intramedullary pinning The study was conducted in eight clinical cases of fracture of long bones, presented to the Surgery Units of Veterinary Hospitals, at Mannuthy and Kokkalai, College of Veterinary and Animal Sciences, Mannuthy, during the period from April 2005 to June 2006.

Animals selected for the study were subjected to treatment of fracture of long bones with external skeletal fixation (ESF) in combination with intramedullary pinning. Those animals which are having a body weight less than 15 kg were treated using ESF with acrylic connection bar and those animals heavier than 15 kg body weight were treated with ESF using stainless steel connecting bar. During the follow up period, animals were subjected to clinical, radiological, haematological and serum biochemical evaluation, both preoperatively and postoperatively and observations were recorded fortnightly, upto eight weeks.

Retrograde intramedullary pinning with Steinmann pin of suitable size that occupied 70% of the medullary cavity at the isthmus was selected through the lateral radiograph. This selection was found satisfactory in all animals except one where mild angulation between the fracture fragments was observed in immediate postoperative radiograph. However, when the fracture gap got filled with sufficient callus, the angular deformity got corrected to normalcy.

The pins were drilled almost parallel to each other in four cases. In other four cases, pins were drilled at an angle of 70 degree from the long axis of the bone, at least two centimetres away from the fracture site.

Use of only two pins in a fragment, use of smooth pins, drilling all pins at almost parallel to each other, drilling pins through fracture line and fixing the connecting bar close to the skin leaving only one centimetre between skin and the bar did not cause any adverse effects, but gave satisfactory results.

By third postoperative day, dogs in four cases were seen to make slight ground contact with the leg. One case showed evidence of radial nerve paralysis but two weeks after implant removal onwards, animal started bearing weight on this limb and showed signs of recovery from radial paralysis. Complete weight bearing and limb contact with the ground was absent in one case until fourth week and the further observation was not possible as it succumbed to death following parvoviral enteritis. As the complication of intramedullary pinning with external fixation technique, two cases developed quadriceps muscle contracture by fourth postoperative week. There was obvious lameness noticed throughout the observation period in one case. This animal showed no callus formation even by eighth week of presentation proceeded nonunion. Also in one case the dog was bearing weight until second postoperative week and later on the animal was recumbent due to spondylosis.

During the entire period of observation all the animals showed normal variation in rectal temperature, pulse rate and respiration rate

External fixator was stable in all animals except two cases, where acrylic and stainless steel connecting columns were used respectively. In one case, distal pin loosening with breakage of acrylic column between the intramedullary pin and first fixation pin occurred mainly because of self mutilation. It could be managed by reapplying another distal fixation pin and acrylic column, which showed progressive improvement in limb usage by sixth week and had sound limb usage after implant removal. One of these animal under the study showed evidence of spondylosis on preoperative radiograph and by second postoperative week the animal was recumbent over the implant side which resulted in bone splintering. This might have occurred due to the strong muscle pull on the femur fragments and to pin loosening and bending.

Mild pin tract drainage occurred in all animals except in two cases. Serous purulent discharge was observed in two animals, where the cause for purulent discharge was self mutilation.

From the immediate postoperative radiograph, sufficient alignment and apposition between the fracture fragments could be achieved in most of the cases except in one, where the Cerclage wire was loosened and the tip of the intramedullary pin was found away from the medullary canal. Mild angulation between the fracture fragments noticed in one, but appeared insignificant clinically. Finally when the fracture gap got filled with sufficient callus, the straightness of the bone was restored to normal. Although immediate postoperative radiograph in one case showed a near perfect apposition, the bone was splintered by second postoperative week as the animal was recumbent over the implants due to spondylosis

Rate of callus formation varied with age of the animal, type of fracture and stability of the apparatus. The fracture gap in three dogs was found progressively filled up with sufficient callus formed by fourth week of observation. Three cases under the study being young growing animals (2 months, 3 ½ months and 11 ½ months respectively) showed rapid callus formation and necessitated the removal of implants by sixth week in one. There was no evidence of callus formation even by eighth week observation in one dog, which resulted in nonunion due to old age.

Mild osteolysis in the distal pin tract could be observed only in one animal from the sixth postoperative week as the result of pin loosening and bending.

The usage of corrugated flexible pipe of one centimetre diameter was found satisfactory for the use of filling the acrylic while used in ESF for the management of femur fracture in animals weighing less than 15 kg body weight. No noticeable thermal necrosis of bone or soft tissue was produced by the heat generated during exothermic phase of acrylic hardening.

The postoperative antibiotic coverage with cephalexin at the rate of 20 mg/kg body weight twice daily orally and routine dressing of pin tracts with povidone iodine was found to be satisfactory in controlling the postoperative infection.

Implants were removed based on the radiographic union and the evidence of visible callus at the fracture site. Removal of fixation pin was done with artery forceps. Removal of intramedullary pin was done with forceps in animals, where tie-in configuration was used. But Jacobs hand chuck was used to remove the intramedullary pin in animals where tie-in configuration was not used and its removal was difficult in one case and hence, it was left in situ.

A combination of external skeletal fixation with intramedullary pin was found to be effective in the animals studied, for countering the torsional or bending forces acting on the long bone fractures, especially the femur and provided good radiographical and clinical union; with early return of functional limb usage.

From the study the following conclusions were drawn,

- The incidence of fractures was more in German Shepherd Dogs and the ages most affected are within the age group below one year.
- Among the long bone fractures, femur fracture was found more.
- ESF with 'tie-in' configuration and intramedullary pinning was effective in stabilizing the fracture of femur in dogs.
- Weight bearing with the Type IA external skeletal fixation in combination with intramedullary pinning technique adopted was seen from tenth day onwards.
- The implants could be removed by sixth week in young animals.
- Pin loosening, breakage of acrylic column etc., were the common complications observed.

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EXTERNAL SKELETAL FIXATION IN COMBINATION WITH INTRAMEDULLARY PINNING FOR MANAGEMENT OF LONG BONE FRACTURES IN DOGS

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ABSTRACT

Long bone fractures especially femur undergo rotational instability when treated with intramedullary pin alone and hence, managed with the combination technique including external skeletal fixation with intramedullary pin in eight dogs presented to the Surgery Units of Veterinary Hospitals, at Mannuthy and Kokkalai, College of Veterinary and Animal Sciences, Mannuthy, during the period from April 2005 to June 2006. All the animals were subjected to clinical, radiological, haematological and serum biochemical evaluation, both preoperatively and postoperatively and observations were recorded fortnightly, upto eight weeks.

The selected patients were subjected to treatment with external skeletal fixation with intramedullary pin and acrylic connecting bar was used in animals which were below 15 kg body weight and stainless steel connecting bars in those animals which were above 15 kg body weight.

Steinmann pin of suitable size that occupied 70% of the medullary cavity at the isthmus was selected and was found satisfactory in all animals except in one animal where mild angulation between the fracture fragments was observed in immediate postoperative radiograph. However, when the fracture gap got filled with sufficient callus, the straightness of the bone was restored to normal.

There was satisfactory use of two pins or only one pin in a fragment, use of smooth pins, drilling all pins at almost parallel to each other, drilling pins through fracture line and fixing the connecting bar close to the skin leaving only one centimetre from skin. But one animal showed no evidence of callus formation even by eighth postoperative week and resulted in nonunion due to old age.

External fixator was stable in all animals except in two animals, where there was implant instability due to self mutilation. Satisfactory alignment and apposition between the fracture fragments were observed in most of the cases

except one animal where the Cerclage wire was loosened and the tip of the intramedullary pin was found away from the medullary canal. Mild angulation between the fracture fragments noticed in one animal appeared insignificant clinically and the straightness of the bone was restored to normal when the fracture gap got filled with sufficient callus.

When compared to stainless steel connecting bar, acrylic connecting bar also provided adequate stability in femoral fracture repair of animals less than 15 kg body weight and provided cheaper alternative to the former as it does not require the expensive components. But, due to the innate nature of a animal in one animal, the acrylic connecting column was broken by self mutilation and after the reapplication of the acrylic connecting column, the fracture stability attained was satisfactory and showed progressive improvement in limb usage from sixth postoperative.

All the animals except in four animals had functional limb usage on the third postoperative day following combination technique of external skeletal fixation with intramedullary pin.

Young growing animals under the study showed rapid callus formation and good radiographic union when compared to old animals. One animal showed no evidence of callus formation even by eighth week which resulted in nonunion.

Complications commonly observed in the combination technique of external skeletal fixation with intramedullary pinning were quadriceps muscle contracture and stifle stiffness. This was obviously observed in young growing animals below one years of age.

The combination technique of external skeletal fixation with intramedullary pinning in the animals studied was effective in countering the rotational and bending forces acting on the long bones, especially the femur. This provided early return of functional limb usage with good radiographic and clinical union.