MANAGEMENT OF FRACTURE OF EXTREMITIES OF LONG BONES IN DOGS

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DECLARATION

I hereby declare that the thesis entitled **"MANAGEMENT OF FRACTURE OF EXTREMITIES OF LONG BONES IN DOGS"** is a bonafide record of research work done by me during the course of research and that this 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 **"MANAGEMENT OF FRACTURE OF EXTREMITIES OF LONG BONES IN DOGS"** is a record of research work done independently by **Remya. V** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Fracture management in small animals has become more and more complex in recent years with wider variety of orthopaedic devices and greater client expectations. More than fifty percent of fractures are seen in young dogs less than one year of age. Due to presence of weaker physis and epiphyseal-metaphyseal area in them, fractures commonly occur in extremities of long bones. From the point of view of treatment these injuries are often unforgiving. Inappropriate treatment of these fractures result in development of degenerative joint disease, periarticular fibrosis and adhesions and premature closure of physis which may lead to permanent loss of limb function.

Anatomical peculiarities of extremities of bones with peculiar contour, adjacency to the joint, presence of physis and the smaller fragment in case of fractures forms the negative side of these fractures, whereas presence of cancellous bone with rich supply of blood and cells, potency of faster healing and good implant holding makes the positive side.

External coaptation of these fractures often result in deformities more severe than that with original injury. Traditional plates are ineffective in extremities, with smaller fragment to place screws, and the twists and curves of the bone here remove option for straight plates from the list (Byron et al, 2002). Bone screws in static and dynamic fashion have been used in fixing fractured extremity but they required more bone trauma, and are successful only in experienced hands. Fixation failures are often encountered with limited bone stock in the area thus increasing the strain on the implant (McCarteney et al, 2007). Moreover these instruments are relatively expensive.

Roush and McLaughlin (1998) has reported the versatility of intramedullary pins. They require minimal instrumentation and can be performed easily and rapidly and when used correctly they gave equal results as other advanced techniques. Intramedullary pins as rush pins, cross pins and parallel pins are used in management of extremity fractures. (Stiffler, 2004 and Cabassu, 2005). Among various internal fixation devices, pinning had the advantages that they cause no interruption to periosteal callus formation; require relatively minimal approach and minimal skill for placement. Anatomic reduction with minimum trauma to soft tissue and bone and a stable, less rigid fixation having minimum impact on physis that is required for articular and periarticular fractures (Denny, 1991), could be met with pinning techniques.

Limitations of a single intramedullary pin must be thoroughly understood and appropriate auxiliary fixation techniques may be used. Using pins at two different angles relative to sagital plane had improved torsional stability and studies proved that cross pins sustained greatest loads to failure (Simpson and Lewis, 2003).

External fixation is an increasingly popular fixation technique in small animal practice wherein pins inserted into bone are clamped to a rigid metal rod adjascent to limb, thus neutralizing forces through the bone. The system is versatile, can be used in a variety of orthopedic injuries with open and closed reduction methods. Substituting connecting bar with acrylic splints made from dental grade non sterile polymethylmethacrylate, can reduce the cost involved (Julie, 2005).

It has been observed that, when fracture occurred at extremity of long bones, being highly susceptible for complications, it raised doubts with veterinary surgeons and prevented them from attempting internal fixation techniques. This necessitated in evolving techniques which are technically and economically viable and can be practiced by any trained veterinarian. Reports on use of a wide variety of implants, from pins to plates, in fixation of these fractures are available. On scanning these available literature, reports on techniques of internal fixation that satisfy the requirements of practicing veterinarian were found scanty.

Hence, the study was undertaken to assess the efficacy of various surgical techniques in the management of fracture of extremity of long bones in dogs, using orthopaedic pins and wires which are more practical and involving comparatively less cost and instrumentation:

Review of literature

2. REVIEW OF LITERATURE

2.1. INCIDENCE

Incidence of fractures of extremities of long bones are described as:

2.1.2. Age

Age of incidence of dogs with femoral fractures was less than 10 months in the survey done by Denny and Minter (1973).

According to Alcantra and Stead (1975), beyond 2 years age, distal diaphyseal fractures were exclusively present in distal femur.

Phillips (1979) stated that average age of incidence of femoral neck fracture and distal condylar fracture was 1.1 years and 7 months respectively and that of distal humeral fracture was 3.8 months.

According to Anderson *et al.* (1990) patients could be classified by age as adult (>1 year) or juvenile (<1 year). The majority of intercondylar fractures (85%) were in adults with a mean age of five years and the mean age of juveniles sustaining the fracture was four months. The mean age of fracture in adults with substantial trauma was 3.1 years and 5.1 years in minor trauma group.

Gibson *et al.* (1991) reported that capital physeal fracture of femur in dogs were observed at an average age of 5.6 months (1.5months to 13 months).

Femoral neck fractures occurred in dogs of more than one year of age whereas distal metaphyseal femoral fractures occurred mainly in young animals less than one year old (83 %) (Aithal *et al.*., 1999).

Fractures involving distal femoral physis (Salter Harris type I and II) were common in pups and kitten of 4 to 11 months old (Harasen, 2001).

2.1.2. Breed

Majority of humeral condylar fractures were seen in terriers (Phillips, 1979).

Denny (1983) observed an increase in incidence of humeral condylar fractures among Spaniels (35 per cent) with lateral condyle mainly affected. Conformation of elbow might have predisposed this breed, as might certain types of activities because many were shooting dogs worked in rough terrains.

Terriers were predisposed to combined fractures of tibial tuberosity and proximal tibial physeal fractures, and terriers and greyhounds were predisposed to tibial tuberosity avulsion fractures (Macias and McKee, 2003).

2.1.3. Pattern Wise

In a survey on stifle surgeries in dogs Denny and Minter (1973) found that of the fractures of distal femur, majority were fractures through epiphysis (epiphyseal separation) followed by supracondylar fractures.

Phillips (1979), reported that 72 per cent of humeral fractures involved condyles and of femoral fractures,16 per cent involved femoral neck and 26 per cent affected distal region. Of the 22 humerus fracture in dogs, only one involved separation of proximal humeral epiphysis, and 16 involved condyle of which 11 were lateral condylar fracture. Of the 49 fractures of radius and ulna, five affected olecranon. Of the 42 fractures of femur, seven were fracture of femoral neck (six intracapsular and one extracapsular) and 11 involved distal femoral condyle (eight epiphyseal separations, three comminuted).Of the 42 tibial fractures, three had avulsion of tibial crest.

In a retrospective study on physeal injuries in dogs, Marretta and Schrader (1983) found that 30 per cent of long bone fractures involved an active physis and physes most actively contributing to the bone length were often involved.

Parker and Bloomberg (1984) reported that 95 per cent of distal femoral fractures were classified as Salter Harris type II of which, in 52 per cent the caudomedial metaphyseal projection remained with the epiphysis.

Majority of distal femoral fractures were short oblique or transverse and distal humeral fractures were transverse or comminuted. 44 per cent of dogs with distal femoral fractures with open physis had non physeal injuries and of physeal injuries majority were Salter Harris type II fractures. (Whiteney and Schrader, 1987)

Eight out of nine single condylar fractures of the distal femur involved medial condyle and the greater incidence of medial condylar fracture over the lateral condylar fracture might be due to the extra support provided to lateral condyle by the femoral attachment of lateral meniscus which prevented the caudal rotation of the fragment whenever it fractured (Carmichael *et al.*, 1989).

Payne (1993) reported that Salter Harris I fracture predominated femoral head and though fracture did not involve articular surface it was intra articular fracture. Luxation of femoral head was associated with avulsion fracture of fovea capitis

Aithal *et al.* (1999) observed that majority of femoral neck fractures were extracapsular and distal metaphyseal fractures of femur, radius and ulna and humerus were short oblique or transverse

Aithal *et al.* (1999) observed that 11.6 per cent of femoral fractures involved neck and 18.7 per cent involved distal metaphysis. 13.04 per cent of tibial fracture involved proximal tibia, and 2.9 per cent of radius and ulna fracture involved proximal region. 29.03 per cent of humeral fractures were distal fractures. No distal tibial and proximal humeral fractures were encountered and epiphyseal fracture of radius and ulna were uncommon (1 per cent). Oblique, spiral or incomplete fractures were commonly seen in age group of 0 to 6 months whereas comminuted and multiple fracture were frequent in age group of 1 to 3 years which could be attributed to the fact that in immature animals bone is more elastic whereas collagen cross linking and mineralisation in adult bone resulted in more brittle tissue. But majority of fracture occurred in young dogs which reflected their inability to cope up with emergencies. There was an increased incidence of hind limb fractures in the study.

According to Harasen (2003a), three in every four long bone fractures in small animals occured in hind limb. Animal seeing any impending trauma coming (automobile) made an effort to flee exposing their hind quarters to the major force of impact.

Articular and periarticular fractures of proximal humerus, femoral neck fractures, avulsion of greater trochanter and combined tibial tuberosity and proximal tibial physeal fractures were uncommon injuries in dogs (Macias and McKee, 2003).

All humeral condylar fractures observed (Guiile *et al.* 2004) were Salter Harris type IV with 86 per cent sustaining fracture through capitulum and the rest through trochlea.

2.1.4. Sex Wise

Distal femoral fracture in dogs had a sex ratio of almost 1:1 (Denny and Minter, 1973).

Incidence of both sexes were proportionately same in study done by Denny (1978) on fractures in dogs

Higher incidence of males were observed in dogs with long bone fractures by Aithal *et al.* (1999)

1.2. ETIOLOGY

Distal femoral fractures occurred mainly with road traffic accident or a fall. (Denny and Minter, 1973).

The initiating trauma for distal femoral fractures was a road traffic accident in 54 per cent, falling from a height in 12 per cent, blows in four per cent, dog bites in three per cent, and causes were unknown with 26 per cent cases (Alcantra and Stead, 1975).

Of the femoral neck fractures in seven dogs, five were with automobile accidents and two had no history of trauma (Phillips, 1979).

Lewis and Bellah (1987) reported a case of subtrochanteric femoral fracture in a five month old Doberman pup due to an automobile accident.

A violent twisting of the limb due to it being caught in some fixed object, or a fall when running were the most common injuries that resulted in single condylar fracture of distal femur in dogs (Carmichael *et al.*, 1989).

According to Prieur (1989), physeal fractures were always caused by trauma, most frequently car accidents or falls

Out of various cases of intercondylar fractures in dogs, supracondylar comminution occurred in 50 per cent cases with minor trauma and in 57 per cent cases that had a substantial trauma (Anderson *et al.*, 1990).

Of the six comminuted supracondylar fracture encountered in dogs, three dogs sustained the fracture following gunshot injuries, two injured with automobile accident and one during a dog fight (Guerin *et al.*, 1998).

Majority of dogs with humeral condylar fractures sustained injury with a fall and occurrence of road traffic accident was less (Rorvik, 1993).

In the survey done by Aithal *et al.* (1999), femoral neck fracture occurred mostly with a fall. Fractures of all long bones generally resulted from traffic accidents or a fall from a height.

2.3. PATTERNS OF FRACTURE OF EXTREMITIES

Pathological fractures were usually transverse and with folded ends (Morgan, 1972).

Denny and Minter (1973) stated that commonly occurring fractures of distal femur fall into three types; supracondylar, epiphyseal, and condylar fractures and of the proximal end of tibia into two types; avulsion of the tibial tuberosity and fracture through proximal epiphysis.

Alcantra and Stead (1975) divided distal femoral fracture in dogs and cats into three classes, as judged by their radiographic appearance as, distal diaphyseal, metaphyseal, epiphyseal – metaphyseal, epiphyseal separations and intercondylar.

According to Culvenor *et al.* (1978), injuries to the distal femoral growth plate were rarely simple types I and II, but most frequently had a type V component which might had substantially contributed to premature physeal closure.

Schwarz and Schrader (1984) described the prevalence of ulnar fracture with dislocation of proximal radial epiphysis (Monteggia lesion) in dogs and cats.

Prieur (1989) reviewed Salter-Harris classification of physeal fractures as type I injuries involving separation of physis, type II involving fracture line running partially through physis and metaphysis whereas type III involved fracture line running partially through physis and epiphysis, type IV involved fracture line running through physis, epiphysis and metaphysis and type V injury crushed the physis .

Simultaneous femoral neck and subtrochanteric fractures were observed in cats (Jeffery, 1989).

Proximal femoral fractures were classified by Simpson and Lewis (2003) as intracapsular which included capital epiphyseal, capital physeal, subcapital and transcervical fractures, and extracapsular which included basilar neck, trochanteric, intertrochanteric and subtrochanteric fractures. Distal femoral fractures were classified as metaphyseal (supracondylar), physeal and epiphyseal fractures. Femoral capital physis of dogs has a gentle L-shaped contour that facilitated reduction of fracture and provided inherent resistance to shear and rotational forces

Histological studies on physeal fractures in dogs done by Johnson *et al.* (1994) proved that in majority of cases the fracture involved not only the hypertrophic zone , but also crossed the physis and separated the reserve zones from epiphysis in certain areas.

Emmerson and Muir (1997) reported a case of bilateral supracondylar femoral fracture in a pup in association with bony lesion like metaphyseal destruction, suggestive of a pathological fracture.

Aithal *et al.* (1999) reported incidence of distal femoral metaphyseal fracture in two dogs suffering from rickets.

According to Macias and McKee (2003) the majority of articular and periarticular fractures in immature animals were two fragmented rather than comminuted and articular fractures overrepresented periarticular fractures.

Fractures of distal humerus were classified into distal shaft, supracondylar, unicondylar, dicondylar and epicondylar fractures and majority of the former two fractures resulted from automobile accidents (Tomlinson, 2003).

According to Beale (2004) capital femoral physeal fracture could occur in growing cats and dogs following moderate or severe trauma, and was more common than hip dislocation.because physis was more fragile than the stronger ligamentous attachment of the femoral head. Subtrochanteric fracture involved proximal metaphysis and occurred as an isolated fracture or in association with femoral neck or diaphyseal fracture.

Distal radius and ulna fracture resulted in caudolateral displacement of distal fragment because of contraction of flexor muscles of antebrachium (Milovancev and Ralphs, 2004).

A pathological fracture should be suspected if a bone fractures due to stress considered being within the normal physiological tolerance of that bone (Wraighte and Scammell, 2006).

2.4. ANATOMY OF BONY EXTREMITIES

Parker and Bloomberg (1984) described anatomical peculiarity of distal femur in small animals. The distal femoral physis has four projections or pegs that fit into respective epiphyseal sockets. The caudal projections are smaller, has a thinner femoral attachment, and seat in deeper depressions than cranial projections.

Beale (2004) described the histology of physis. Physis can be divided into four distinct areas: zone of resting or reserve cells, zone of proliferating or maturing cells, zone of hypertrophying cells and zone of calcified cartilage. Reserve cells, which are important for continued physeal growth, remained with epiphyseal fragment.

Strand (2007) stated that growth plate consisted of a plate of hyaline cartilage, the physeal cartilage and was seen in radiographs as a radioluscent line surrounded by diffuse relatively increased bone opacity.

2.5. PHYSIOLOGY OF BONE EXTREMITY

According to the radiological observation made by Smith (1966) in grey hounds, fusion of greater trochanter and proximal epiphysis of femur and distal femoral as well as distal tibial epiphyseal fusion happened at 11 months of age.

The epiphyses found to fuse the last were proximal epiphysis of humerus and area of tibial tubercle

The physis is responsible for linear growth of the shaft and the articular cartilage for the growth of epiphysis. Anastamosis between the capillary network on the epiphyseal and metaphyseal sides of physis following an injury might stop growth in this area and by irregular growth of physis, malformation of bone occurred (Prieur, 1989).

Strand *et al.* (2007) stated that endochondral ossification of the growth plate accounted for most of the linear growth of the long bones. Cessation of this growth coincided with radiographic closure of the growth plate. Radiographic closure had occurred when there was no radioluscent line visible on the physeal area.

2.6. BIOMECHANICS OF FRACTURES OF EXTREMITIES OF BONES

According to Wolf (1954), supracondylar fracture of femur resulted in over riding with the action of quadriceps on proximal and gastrocnemius along with superficial flexor on distal fragment. Ineffective reduction and immobilization resulted in permanent deformity

Denny *et al.* (1971) stated that the state of fusion of epiphysis was a critical factor in determining the type of injury that occured following trauma, in the region of hip joint.

Fracture of distal femur in dogs and cats mostly occurred with the lower limb fixed. In a dog with an open growth plate, an anterior, or anterolaterally directed force would tend to displace the metaphysis first upwards and then forwards from the epiphysis, at the same time shearing one, or both metaphyseal projections, leaving them in situ in their epiphyseal depressions (Alcantra and Stead, 1975).

Metaphyseal chip in Salter Harris II fractures of femur was associated with inability of bone to withstand compression as effectively as cartilage. (Culvenor *et al.*, 1978).

According to Marretta and Schrader (1983), Salter Harris types I, II, III and IV injuries were results of shearing and/or avulsion forces and type V of crushing injuries. Most of growth deformities occurred with type V injuries of distal ulna because conical shape of physis transmitted a crushing injury with shearing or bending forces and these deformities most likely affected large breed pups with much remaining growth potential. Deformities included radius curvus, external rotation of paw, valgus deformity of carpus etc, due to failure in synchronous growth of radius and ulna. Lateral humeral condylar fractures were more common in dogs because shearing forces were transmitted to condyle through its articulation with radial head and most often the fracture resulted from a fall

Schwarz and Schrader (1984) stated that pathomechanics involved in creating lesion may help the clinician in choosing a mode of treatment to counteract the disruptive forces.

Force needed to result physeal fracture in juveniles was much less than that needed to cause shaft fractures in adults because the strength of the physis was only 20 to 50 percent of that of bone. Additional trauma to the germinal zone or obliteration of epiphyseal or metaphyseal vessels would complicate the injury (Prieur, 1989).

Avulsion of tibial tuberosity was relatively rare and occurred with extrinsic factors such as direct trauma, usually in 3 – 5 months old pups of any breed. It could also occur with intrinsic factors, such as muscle pull, in older pups of 5 – 8 months age, with a higher occurrence in grey hound and bull terriers (Skelly *et al.*, 1997).

When the animal fell and landed on its forelimbs, the front paw striked the ground and got fixed during which central axis of body tilts cranially to concentrate stress at middle and distal radius and ulna resulting in fractures (Aithal *et al.*, 1999).

Caudal displacement of tibial proximal epiphysis might occur with relative immobility of proximal epiphysis in relation to femoral condyles, where it was held with cruciate and collateral ligaments. Following fracture of proximal tibial physis patellar ligament pulled the anterior tuberosity resulting in its cranioproximal displacement and hock extensors displaced epiphysis and femur condyles caudally (Clements *et al.*, 2003).

Cabassu (2005) stated that fractures through the physis were more common than joint luxation in immature patient because the cartilaginous plates created weak focal points that were more prone to injury.

The direction of force that influenced the pattern of fracture must be diagnosed from clinical and radiological assessment of the fracture, because it must be reversed during manipulative reduction, and also helped to determine duration and success of healing. (Wraighte and Scammell, 2006).

2.7. CLINICAL SIGNS

Carriage of limb in slight adduction, swelling in the region of hip, pain on manipulation of the joint and crepitus at hip were features found in dogs with simultaneous epiphyseal separations and fracture of neck and greater trochanter of femur (Denny *et al.* 1971).

Pettit and Slatter (1973) reported the case of an 8 month old dog with avulsion of tibial tuberosity with non weight bearing lameness of hind limb with foot carried , paw slightly flexed and rotated medially. Palpation of stifle revealed pain and there was a mild diffuse swelling over craniolateral aspect of proximal tibia.

Bennett (1975) observed an increased incidence of femoral epiphyseal separation and neck fracture in young cats (<1 year age) with associated clinical signs as with severe hind leg lameness, adducted limb, crepitus, and a shorter limb kept in caudal extension and all had a rapid return to function with excision arthroplasty.

The clinical signs of distal condylar fracture of femur were of sudden onset with carrying leg lameness along with pain and swelling at the stifle (Carmichael *et al.*, 1989).

According to Payne (1993), dogs with humeral condylar fracture had a weight bearing lameness in some instances with pain and crepitus in the elbow joint. Neurologic function of radial, ulnar, and median nerves should be evaluated by checking for sensory perception on the cranial, caudal and medial aspects of paw respectively. Animals with femoral head fracture frequently presented with a partial or non-weight bearing lameness, and a painful hip. Intra articular fracture of femoral condyles resulted in non-weight bearing lameness with pain and crepitus associated with stifle.

Muir and Manely (1994) reported abnormal withdrawal reflex on fore limb of a dog sustaining fractures of proximal radius and ulna and a comminuted fracture of humerus, which returned to normal following internal fixation of fractures. The neurological deficit could be due to neuropraxia as a result of extensive soft tissue trauma.

An animal with a fracture was often presented with limb dysfunction, pain, fracture instability, overlying soft tissue trauma, abnormal posture or limb function, or crepitus (Roush and McLaughlin, 1998).

Tomlinson (2003) reported that spinal trauma, brachial plexus injuries, and peripheral nerve injuries occurred with humeral fractures. Partial radial nerve damage (neuropraxia) associated with fracture resolved quickly once fracture was stabilized.

2.8. MANAGEMENT OF FRACTURE OF EXTREMITIES

2.8.1. **Initial Considerations**

Roush (2005) opined that the first and most important actions in fracture diagnosis and management were to thoroughly assess the traumatized animal for other injuries of core body system, particularly occult injuries to thorax and abdomen., eliminate or stabilize life threatening injuries to the animal and provide immediate relief for pain and discomfort from injuries.

2.9. TREATMENT

2.9.1. Conservative

Conservative treatment of femoral epiphyseal separations and neck fracture in young cats resulted in rarefaction of femoral neck and proximal shaft and acetabular remodeling. However all of them had good motion in hip joint after several months since the amount of displacement at fracture site was only slight. 15 per cent of cats had concurrent proximal femoral and greater trochanter epiphyseal separation (Bennett, 1975).

Simpson and Lewis (2003) opined that closeness to abdomnel wall and bulky surrounding musculature limited use of coaptation for femoral fracture.

In a study on proximal femoral capital epiphyseal separations and femoral neck fracture in cats, Perez-Aparicio and Fjeld (1993) found that all cats with femoral capital epiphyseal separations left untreated developed pseudoarthrosis in the coxofemoral joint. Out of five cases with femoral neck fracture left untreated, three showed spontaneous healing and two developed pseudoarthrosis.

Langely-Hobbs *et al.* (1996) compared and assessed various casting materials used in small animals and found that plaster of Paris materials were cheaper with minimal requirements for application, were comparatively radiolucent and were easier to remove.They recommended Cellamin for animals greater than 10 kg and Gypsona for animals less than 10 kg, for immature animals or when the cast is used as a supplement to internal fixation.

2.10. INTERNAL FIXATION

Denny (1991). recommended internal fixation in immature animals when fracture resulted in excessive rotational deformity or shortening or when fracture involved displacement of articular surface or when growth plate was involved. When internal fixation was done in these situations extreme care must be taken to avoid damage to germinal cells and epiphyseal side of growth plate

Frequent lavage with sterile saline solution, gentle traction and correct instrumentation was recommended in orthopaedic surgeries by Rochat and Payne (1993).

Stiffler (2004) opined internal fracture fixation utilized anatomic reduction of each fracture fragment as each fragment was directly visualized, returned to its original location and rigidly stabilized promoting implant and inter fragmentary load sharing and direct bone healing.

2.11. EXTERNAL FIXATION

Carmichael (1991) described the application of four pin unilateral, uniplanar fixator following the restoration of fracture in position. Pins one and four were inserted at the proximal and distal ends of the bone, as close as possible without entering joint at approximately 65 degree to the long axis of bone to exit the far cortex which was followed by connection of connecting rods with four clamps. Using the middle clamps as drill guides the insertion was repeated for pins two and three as near to fracture as possible. The pins in each bone should form a converging angle of 45 degree.

According to Johnson (2003), suspending the limb from the infrastructure of a ceiling or using a pulley system to suspend the limb oriented the limb in a vertical position and used the weight of the animal to distract and align the fractured radius or tibia

Aseptic technique must be followed in applying external fixator and the technique could be done open or closed. Closed reduction was less traumatic but usually resulted in inadequate reduction and hence often limited approach open reduction was done. A minimum of two pins per fracture segment was necessary to prevent rotational instability. Entire apparatus must be protected with bandages and removal of apparatus could be done with sedation or general anaesthesia (Canapp, 2004).

Julie (2005), opined that substituting connecting bar with acrylic splints made from dental grade non sterile polymethylmethacrylate, can reduce the cost involved in external skeletal fixator.

2.12. PRINCIPLES OF EXTRIMITY REPAIR

Whitney and Schrader (1987) opined that, when anatomic reduction could not be performed, over reduction was preferred over under reduction especially with distal femoral fractures

Adaptation osteosynthesis was often preferred to achieve sufficient clinical union in physeal fractures because physeal fractures healed quickly and one could use weak implants for fragment fixation. The vascular supply to the epiphyseal fragment must be preserved (Prieur, 1989).

Church and Schrader (1990) opined that, there was no correlation between weight of dog and diameter of medullary cavity of femur and radiographic measurement of diameter of the femoral shaft was not always helpful predicting the diameter of intra medullary rod needed for repair.

Denny (1991) explained the AO/ASIF method to restore full function of limb as quickly as possible. Distal physeal fractures occurred in immature patients with Salter Harris II type been the most common. They were usually repaired with pins, avoiding any configuration that would compress physis. Cross pins, single intra medullary pins and cross pins, lag screws (for type IV) or rush pin technique could be used here. According to him early removal of pins following healing may decrease chance of premature closure of physis.

According to Rochat and Payne (1993), general factors that must be considered in fracture fixation technique included the location and configuration of fracture, concomitant orthopedic and soft tissue injuries, age, size, temperament of patient, pre-existing disease, owner compliance, experience of surgeon, instruments available and expected level of performance of animal.

Piermattei and Flo (1997) recommended 18 G wires for tension band wiring in large breed dogs, 20G in medium breed dogs and 22 G in small breed dogs

Roush and McLaughlin (1998) opined that, intra medullary pins with or without ancillary fixation devices such as wire in full cerclage fashion, were the most commonly used fixation device in veterinary practice. When used correctly they provided three points of fixation; at the point of insertion, the isthmus, and the distal cancellous bone. A pin's diameter should be 70 to 90 per cent of the medullary cavity diameter. They could be placed in the medullary cavity in either normograde or retrograde fashion.End threaded pins had no holding advantages over smooth pins and often broke at thread shaft junction. Pin migration with movement of fracture site or with action of adjascent soft tissues on pin end suggested impending failure since pins rarely migrated from stable and healed fractures. Otherwise removal of pin was unnecessary.

Beaver *et al.* (2000) stated that interfragmentary K wire with internal fixation helped to neutralize rotation, shear, tension and possibly tensional forces.

Langley-Hobbs (2004) stated that fracture reduction could be a time consuming part of any fracture repair, even after applying recognised methods and instruments designed to facilitate this part. Identifying the direction of displacement and applying constant opposing stress to assist reduction was usually employed.

Internal fixation was usually disruptive to the biologic environment though it provided good mechanical support but required a surgical approach disrupting the soft tissue and vasculariy surrounding the fracture (Stiffler, 2004).

Orthopedic pins were used for internal fixation as a primary method of stabilization, but more frequently in combination with ancillary devices. Steinman and Kirschner wires were the two types of pins available. Pins placed in the medullary cavity neutralized bending forces in all directions, but alone won't resist compressive, torsional and shearing forces. Pins should engage both distal and proximal cortical surfaces. Kirschner pins were smaller than Steinman pins and were used to stabilize smaller bone fragments. Cross pinning was the use of small divergent pins to stabilize fractures close to the joint (Salter Harris type I). Exiting pins through cortical bones increased stability. Once implants were placed, they were not usually removed unless complication aroused (Stiffler, 2004).

K wires were used often for fixation of physeal fractures to minimize trauma to germinative cells and was advised to be left in place after healing to avoid epiphysiodesis along pin tract. Parallel pins had minimum impact on growth plate whereas intra medullary pin placed across growth plate had serious consequences (Cabassu, 2005).

According to Rovesti *et al.*. (2006) any fracture might be more easily reduced if subjected to traction because traction counteracted muscle contraction and shortening. The intervals between trauma and surgical intervention had a significant effect on duration of traction required for reduction, but not the maximum traction load applied.

Matis (2007) opined that cancellous bone had advantage from biologic point of view because blood supply to the area was better and hence fracture healed rapidly, however reduction must be anatomic and precise.

2.13. APPROACH

A craniolateral approach to the canine elbow through a curvilinear incision over lateral epicondyloid crest passing cranially and ending slightly distal to radial head, was excellent without damaging any primary supporting structures of the joint for the repair of lateral condylar, supracondylar and intercondylar fractures (Turner and Hohn, 1980).

Carmichael *et al.* (1989) used arthrotomy for open reduction and internal fixation of condylar fracture of distal femur. A parapatellar incision with sectioning of joint capsule medial or lateral to patella (depending on direction of insertion of implant) was used.

Piermattei and Greely (1966) recommended medial approach for correction of supracondylar fracture of humerus because exposure was better as lateral approach was obscured by extensors of on lateral epicondyle. Craniolateral incision to approach hip gave limited exposure of femoral head. Lateral approach to stifle joint was preferred over medial approach for reduction of supracondylar and epiphyseal fracture because of superior exposure of fracture and ease of insertion of pins.

Fischer *et al.* (2004) used a modified craniolateral approach to gain access to the hip joint of cats with fracture of femoral capital physis. Here the skin incision was made in a cranioproximal to caudodistal direction to facilitate placement of K wires.

Guerrero *et al.* (2005) advocated a ventromedial approach to the hip joint for repair of proximal femur physeal fracture in dogs which helped direct visualization of fracture making reduction and fixation easier, and facilitated countersinking of implants below joint surface following normograde insertion. Moreover the position of implants in the femoral epiphysis could be directly assessed intra-operatively allowing minimum number and size of implants placed.Craniolateral approach carryied risks of incorrect fracture reduction, placement of implants in the joint space or poor bone purchase of implant. Also insertion of implants from articular surface using a craniolateral or dorsal approach required transection of round ligament which may result in joint instability and degenerative joint disease.

Lateral approach to elbow joint was relatively less invasive than a bilateral or transolecranon approach. Medial approach was hampered by positioning, presence of neurovascular structures and inability to check joint alignment but it provided a better surface for plating i.e., on the medial side of humerus (McCartney *et al.*, 2007).

2.14. REPAIR TECHNIQUES

Wolf (1954) reported that treatment of oblique supracondylar femoral fracture with cruciate screws proved inexpensive, simple, and allowed early ambulation without ancillary fixation devices.

Kumar *et al.* (1981) recommended cross pinning technique for compound subarticular fractures in bovines. Subarticular fractures of long bones especially when compound were difficult to repair satisfactorily Cross pinning with the pins anchored on both bone cortices obliquely provided good stability preventing deviation in both direction and dispersed tension uniformly at the four insertion points.

Leger *et al.* (1982) reported successful use of AO hook plate for subtrochanteric metaphyseal fractures of femur. According to them for mechanically unstable fractures like fractures in extremities of bone, the use of a hook plate which provided a three point fixation within the relatively short bone, allowed more rigid fixation than pinning technique.

The ideal method to repair fractures involving growth plate was with K wires or small Steinman pins placed across physis with as little deviation from long axis of bone as possible. But it was often easier to insert K wires in cruciate pattern and this had little tendency to affect longitudinal bone growth. The pins or wires should not occupy more than 20 per cent of surface area of growth plate and provided good stability as there was enough cancellous bone in young, for the pins to embed (Denny, 1991).

Joyner *et al.*. (2004) demonstrated the successful use of a hybrid external fixator to repair a periarticular fracture in a young Patagonian cavy. According to him, circular fixators were particularly advantageous for periarticular fractures, with segment too small to allow traditional transfixation pins or screws and the rapid healing could be ascribed to young age of animal, minimal trauma with fixation and good owner compliance.

Condylar fractures should be repaired rigidly using one or more lag screws and anti-rotational wires following anatomic reduction of articular surfaces and when intra medullary pinning was done, normograde insertion was preferred as it avoided injury to sciatic nerve (Beale, 2004)

2.14.1 Femur

Denny *et al.* (1971) reported satisfactory outcome of excision arthroplasty along with internal fixation of greater trochanter with intra medullary screw, in managing simultaneous epiphyseal separations and fractures of the neck and greater trochanter of femur in dogs. This was done because of the difficulty in obtaining satisfactory reduction and fixation of femoral head and because of high risk of avascular necrosis of femoral head following an intra capsular fracture.

Denny and Minter (1973) reported successful repair of distal femoral fracture in a dog with a single Steinman pin.

According to Alcantra and Stead (1975), Rush pins offered best chance of good functional result, with less risk of growth plate interference, in the repair of distal femoral fractures in dogs and cats. Incidence of lameness was greater when screws were used and in immature bone it provided less grip and interference with bone growth was likely.

Parker and Bloomberg, (1984) compared the success rate of repair of distal femoral physeal fractures in small animals treated with multiple pin technique (MPT) and modified intra medullary pin technique (MIPT). In MIPT, retrograde pin insertion with the centre of projections in metaphysis as reference point was used and in rotationally unstable fractures an additional K wire was placed obliquely. All fractures healed in 3 to 4 weeks with a premature closure of physis. No untoward clinical signs were associated with cartilage penetration. Early fixation failure associated with under reduction of fracture and poor pin fixation in distal fragment were seen in multiple pin technique but correct pinning techniques in both groups gave excellent three point fixation.

Lewis and Bellah (1987) reported the success of using a double hook plate in repair of subtrochanteric fracture of femur in a five month old pup. The technique overcame the previously reported complications of proximal femoral fracture repair like developmental deformities of femoral neck, chronic lameness(with intra medullary pinning),placement of screws across physis damaging the cartilage cells(conventional bone plate)etc.

Dynamic intra medullary crosspinning was a versatile technique that could be adopted to most fractures involving distal third of femur in small animals. Whenever fracture was located just above metaphysis, a larger pin or an additional medial or lateral pin were necessary because the area was devoid of cancellous bone thus reducing the pin purchase (Whitney and Schrader, 1987).

Kuzma *et al.*, (1989) advocated articular lag screw fixation of femoral capital physeal fractures in dogs which was simple and less time consuming, allowed accurate reduction and provided rigid fixation. The technique allowed direct visualization of epiphysis during surgery thus overcoming disadvantages of traditional insertion of implants in blind fashion from third trochanter into epiphysis such as malalignment of fracture, overpenetration of articular cartilage by the implant and insufficient thread purchase in the epiphysis.

Gibson *et al.*, (1991) recommended divergent K wires for repair of femoral capital physeal fractures in dogs because of the technical easiness of placing K wires as well as, K wires directed into dorsocentral aspect of epiphysis would achieve maximal bone purchase. The interlocking shape of physis gave rotational stability to the repair.

Piermattei and Flo (1997) advocated overreduction of distal femoral fractures as it prevented patellar impingement and when retrograde pinning was done, adduction of limb during pin insertion prevented possibility of sciatic nerve damage. As single intramedullary pin was associated with instability, an antirotational K wire should be added in their fixation.

Lipscomb and Muir (1998) reported the successful repair of Salter Harris type III fracture of proximal femoral physis in a pup using lag screws. Luxated hip was repositioned by extracapsular stabilization using nylon sutures.

Aithal *et al.*, (1998) reported good functional outcome of supracondylar fractures of femur in dogs, with single intra medullary pin fixation through intercondyloid fossa. The technique required less tissue manipulation, time, and trauma when compared to dynamic cross pinning using rush pins, whereas the later provided more stability and early fracture healing.

In a study conducted by Lorinson *et al.*, (1998) it was observed that a centrally placed pin might be safely driven into the proximal femoral epiphysis (PFE) to a distance equal the 75 per cent to 80 per cent of radiographic depth of controlateral PFE or radiographic width of the pecten of the pubic bone at its narrowest point (measured from the ventro dorsal radiograph of the pelvis).

Stigen (1999) reported the successful use of normograde intra medullary pinning for the repair of supra condylar femoral fractures in dogs and cats. The technique involved insertion of one or two pins from the stifle joint (through a point just cranial to origin of caudal cruciate ligament) into the proximal femur without extending above the level of femoral neck. Pins were not removed in any case. There were no obvious differences in outcome regarding species or age of affected animals.

According to Harasen (2001), distal femoral fracture could be surgically stabilized by placement of cross pins, dynamically loaded cross pins, or single intra medullary pin. Of these, cross pins sustained the highest load to failure when subjected to torsional load, while dynamically loaded cross pins sustained almost 25 per cent less tensional load, but allowed fracture fragments to spring back into reduction after release of force. The intra medullary pin withstood two third of torsional forces sustained by cross pins.

Simpson and Lewis (2003) stated that contraction of muscles and fibrosis made distal femoral fractures difficult to reduce. Overreduction was advocated to improve implant purchase in epiphysis and was preferred over underreduction. Fixation could be achieved by single or multiple intra medullary pins, static or dynamic crosspinning, and lag screws. Intra medullary pin and an interfragmentary K wire had supreme stability and static and converging cross pinning techniques sustained greater loads to failure.

For the repair of femoral capital physeal fractures, screws or Steinman pin were inserted from caudolateral surface of femur just distal to greater trochanter and advanced along the neck of femur to engage the epiphysis (Ewoldt *et al.*, 2003).

Distal metaphyseal fracture of femur in a three month old pup was managed successfully by normograde intra medullary pinning through intercondylar fossa and cross pinning with K wires. Faster healing was noticed by the end of the fourth week with marked improvement in clinical and radiographic features (Ganesh *et al.,* 2004).

Guerrero *et al.* (2005) reported successful repair of femoral capital physis fracture in a dog using a ventral approach and placement of two K wires. Following fracture reduction a smooth K wire was inserted in the fovea capitis femoris, directed towards third trochanter through femoral neck avoiding trochanteric fossa and a second one inserted cranial to the first directed caudally to cross the first wire, both pins countersunk. Seating pin in fovea allowed deeper countersinking and reduced risk of damaging articular cartilage. Placement of lag screws required transection of capsular attachments to femur neck thus reducing blood supply to femoral head, enhancing risk for avascular necrosis. Fixation of implants with craniolateral approach was complicated by inadequate fixation.

Beale (2004) opined that fixation of single condylar fracture of distal femur in dogs could be done effectively with K wires or lag screws. A small diameter pin that did not fill the medullary cavity was sufficient for internal fixation of canine distal femoral fractures. When properly placed, the pin should bend slightly at the fracture site and along the caudal cortex providing a three point fixation.

2.14.2. Tibia

Dingwall and Smith (1971) reported a suture technique for the repair of avulsion of tibial tubercle in dogs.

Pettit and Slatter (1973) employed a modified tension band wiring for the repair of avulsion of tibial tuberosity in an eight month old dog using two kirschner wires placed at converging angles with tips bent upwards, and the tension band wires attached to each stabilizing pin for additional strength. Screw or pin fixation of the fracture should be supplemented with external coaptation in extension to relax the muscle and prevent implant failure.

Leighton and Taylor (1983) reported a case of traumatic avulsion of tibial tubercle in a spayed cat. The fracture was repaired using tension band wiring to offset the pull of quadriceps muscle. The K wires used extended into caudal aspect of knee, penetrating caudal cortex of proximal tibia but did not create any problem

In a study Neat *et al.* (2006) observed decreased ease of workability of the large wire used in tension band wiring

Avulsion of tibial tuberosity could be reduced by extending stifle according to Boudrieau (2003)

Piermattei and Flo (1997) recommended hooking patellar ligament at insertion and applying slow gentle traction to fatigue quadriceps muscle for reduction of avulsion of tibial tuberosity.

Combined tibial tuberosity and proximal tibial physeal fracture were best repaired by reducing and stabilizing former with one or two pins and a tension band wire. Since the tuberosity was connected to proximal epiphysis, repair of tuberosity resulted in concomitant reduction of epiphysis (Macias and McKee, 2003).

Alvarenga *et al.*, (1982) reported the successful repair of proximal tibial epiphyseal separation in an eight month old German shepherd dog using two kirschner wires inserted in cross pin fashion.

2.14.3. Humerus

ASIF screws proved to be more effective than Sherman screws in fixation of humeral condylar fracture in dogs with 77 per cent dogs regaining normal limb function in four weeks (Denny, 1983).

K wires were used to fix supracondylar fracture of humerus in immature animals due to restricted bone stock (Anderson *et al.*, 1990).

Intra medullary pin could be used to attach humeral condyles to the metaphysis and an additional pin from lateral epicondylar crest added stability (Tomlinson, 2003).

Guile *et al.*, (2004) advocated self compressing orthofix pins as primary fixation device in repair of humeral condylar fractures in dogs though it was associated with seroma formation. Fixation using lag screw was technically more difficult particularly in skeletally immature dogs with softer bone whereas K wires did not provide interfragmentary compression and wire migration (observed even after 3 months) necessitated removal of implants.

Fixation of fractures of proximal humerus should be accomplished with two K wires crossing physis perpendicularly in young animals and with lag screws in animals close to maturity (Matis, 2007).

Au *et al.*, (2008) described the use of a transileal rod articulated with a modified type I external fixator for stabilization of dicondylar humeral fracture (Salter Harris IV) in a skeletally immature dog. The technique avoided implant application in close proximity of fracture which might have resulted in vascular disruption, osteopenia and delayed healing. K wires placed in cross pin fashion were minimally disruptive to both bone and soft tissue in comparison to bone plating and provided sufficient stability when combined with an external fixator.

2.14.4. Radius and ulna

Muir and Manely (1994) reported successful repair of a comminuted fracture of proximal radius and ulna in a dog with multiple limb fractures using a dynamic compression plate, placed subperiosteally on the caudal surface of ulna, as a neutralization plate.

In a study conducted by Tyagi *et al.*, (2002), short oblique fractures of olecranon in adult dogs was repaired with stainless steel plate (group I), tension band wiring (group II), and single cancellous lag screw (group III), of which cancellous screw fixation in a lag fashion proved to be easiest, less time consuming and requiring minimal soft tissue manipulation and tension band wiring was the most difficult, more time consuming and with highest degree of soft tissue manipulation. Also the tension band wire got loosened while bending the cut ends of twisted knots towards bone surface.

Limited open approach and external fixation was recommended by Milovancev and Ralphs (2004) in repair of radius and ulna fractures. Though bilateral fixation was preferred, the anterior curve of radius often precluded their use and unilateral pins might be substituted. Type Ia frames was applied to medial or craniomedial aspect. Complications included pin loosening, pin tract drainage, infection, valgus or rotational malalignment, nonunion and pin breakage.

Bone plates, (including T plates and hook plates), cross pins and external skeletal fixators might be used to correct distal periarticular radial fractures (Macias and McKee, 2003).

2.15. POST OPERATIVE CARE

Post operative analgesia was advocated by Miller (2004) to avoid reflex inhibition and to promote early limb usage. The key to early active motion was controlling inflammation and pain

Meloxicam is in the enolic acid class of NSAIDs and has analgesic, antiinflammatory, and antipyretic properties and was proved to be effective in management of post operative pain in dogs. Lameness, stiffness and pain on rising improved in dogs treated with the drug as reported by Curry *et al.* (2005).

2.16. HEALING

Denny and Minter (1973) reported that distal femoral fractures repaired using lag screws healed with minimal callus formation and premature closure of the physis occurred in all cases.

Healing occurred rapidly in all dogs with physeal injuries and Salter Harris type II injuries were most common (Marretta and Schrader, 1983).

Early post operative use of fractured limb enhanced healing due to improved circulatory status and blood supply to the area, decreased muscle wasting and osteoporosis. Stress on fractured ends from weight bearing promoted healing by stimulation of osteogenesis (Lesser, 1984).

Lewis and Bellah (1987) reported extensive callus formation following repair of subtrochanteric femoral fracture in a pup, which was attributed to traumatic periosteal disruption at the time of injury and surgical periosteal elevation rather than to instability at the fracture site. Prolific periosteal responses were not uncommon in immature dogs because of increased periosteal activity during appositional bone growth.

Rochat and Payne (1993) opined that fractures healed quickly in younger animals and required less rigid fixation.

The distal radial fractures of toy breeds were prone to non-union because of minimal vascular supply to the fracture site with limited soft tissue coverage and an extremely small medullary canal in this region (Rochat and Payne, 1993).

Cancellous bone healed more rapidly than cortical bone and occurred with little external callus. This was due to larger area of bone contact and greater number of active bone cells that were present at the cancellous bone region (Wraighte and Scammell, 2006).

2.17. POST OPERATIVE MANAGEMENT

Denny (1983) stated that pre mature weight bearing following internal fixation of humeral condylar fracture might result in re- fracture, and for the first three weeks further support should be provided with a body cast. Generally, a joint should not be immobilized after repair of intra articular fracture as this can lead to joint stiffness. However, this was only a transient problem

Following external fixation of fracture, discharge from pin sites might be carefully cleaned, but pin/skin interface should not be cleaned and allowed to granulate, sealing the area. Pins usually loosened especially when animal was using the limb (Carmichael, 1991).

Auer *et al.*. (1996) stated that postoperative management was a very critical and very important aspect of fracture management. Analgesics should be administered to reduce pain in the injured limb which prevented, continous overload of contralateral limb creating a varus deformity. At the same time some sense of pain was important to protect injury from additional trauma and breakdown of the fixation.

Roush and McLaughin (1998) recommended a one time administration of a first generation cephalosporin at 20 mg/kg intramuscularly and 20 mg/kg intravenously (40 mg/kg total dose) to provide prophylactic antibiotic coverage for up to 5 hours of open procedure time.

Roush and McLaughin (1998) recommended restriction of unsupervised patients to cages or small runs with good solid flooring and if supervised, animals might be allowed brief activity outside when necessary, following fracture repair. Immediate controlled physical therapy including passive range of motion was beneficial to maintain early range of motion and promoted early limb usage. External coaptation or external fixators might be protected from damage by the patient (Elizabethan collars may be used if necessary), moisture, or other factors.

Rochat (2001), recommended use of antibiotics in clean procedures when implants were placed, moderate to severe tissue trauma was present, or if the procedure lasted for more than two hours. The antibiotic must be a broad spectrum bactericidal and cefazolin sodium was an appropriate choice.

Penicillins, cephalosporins and aminoglycosides effectively penetrate infected and normal bone. Cefazolin, a first generation cephalosporin, was effective against Staphylococcal organisms, had relatively long half-life, and achieved excellent penetration into bone (Bubenik and Smith, 2003).

2.18. EVALUATION OF FRACTURE REPAIR

Distal femoral fractures in dogs and cats were repaired using Rush pins, lag screws and K wires. 62.5 per cent of those re-examined were not lame, 29.2 per cent had virtually normal function but occasional slight lameness present (possibly with osteoarthritis), and 8.3 per cent had poor function and permanent lameness (Alcantra and Stead, 1975).

Culvenor *et al.* (1978) reported that after repair of created distal femoral physeal fracture in dogs using single intra medullary pin inserted through intercondylar fossa in normograde fashion (group A) and using two fine intra medullary pins inserted in retrograde fashion (groups B and C), limb function started as early as day 1 after surgery in some dogs, was at least grade 2 (slight use) in all dogs within a week, and grade 3 (slight limp) within 2 weeks. Grade 4 (normal function) was not achieved in most dogs until after pins were removed. Groups B and C used the limbs earlier than group A dogs and there was articular deficit in group A dogs. Double pin fixation was hence advocated which gave earlier limb usage and the fine pins followed the curvature of bone preventing cortical penetration, and when single pin was used retrograde insertion was preferred

Doyle (2004) stated that functional outcomes were true measures of successful fracture management .

93 per cent of small animals with distal femoral fracture repaired with dynamic cross pinning with or without transcondylar screws, K wires or

cerclage wires had good or excellent limb function, and 7 per cent had poor limb function, majority of which had pin migration creating lameness (Whitney and Schrader, 1987).

Sumner-Smith (1993) defined degree of lameness as: 0-sound;1-occasionally shifts weight;2-mild lameness at a slow trot;3-mild lameness;4-obvios lameness while walking,5,6,7-degrees of severity,9-places toe while standing, carries limb when trotting;10-unable to put the foot on the ground.

Limb function following repair of intercondylar fracture in dogs, was assessed on the basis of a scoring system: Excellent-Apparently normal limb function without evidence of lameness or stiffness; .Good - Normal activity with full weight bearing most of the time, occasional stiffness after rest or exercise; Fair -Functional limb, but with frequent lameness and Poor – Non functional limb or marked lameness. Excellent results were observed in 64 per cent cases and 14 per cent dogs had adverse affection of their working lives (Anderson *et al.*, 1990).

Fischer *et al.*, (2004) determined the severity of clinical lameness in cats having femoral capital physeal fractures repaired using K wires by results of clinical evaluation, including passive range of motion and signs of pain, was found to be continuously improving.

Following normograde intramedullary pin fixation of supracondylar fracture of femur, the weight bearing score was assigned as follows. While standing, the weight bearing was scored as 0- test limb not touching; 1 – only toe touching; 2 – full paw touching. During walking and running weight bearing was scored as 0 – carrying the limb; 1 – occasional touching of toe/paw; 2- frequent touching of toe/paw 3 –touching toe on every step with partial weight bearing; 4-touching the paw on every step with full weight bearing. The net weight bearing score was calculated by adding the scores obtained at standing, walking and running (range 0-10) in an interval of 2 weeks (Aithal *et al.*, 1998).

Final assessment of clinical lameness following repair of humeral condylar fracture in dogs was scored by Cook *et al.* (1999) as: 0-no observable lameness, 1-intermittent,mild weight bearing lameness with little if any change in gait, 2-consistent,mild weight bearing lameness with little change in gait, 3-moderate weight bearing lameness with noticeable change in gait, 4-severe weight bearing lameness, toe touching only, 5-non weight bearing lameness.

2.19. ROLE OF RADIOGRAPHY

2.19.1. Diagnosis

In dogs with simultaneous epiphyseal separations and fracture of neck and greater trochanter of femur, a ventro-dorsal radiograph of hip revealed a separation of proximal epiphysis or fracture of femoral neck, but would not always show fracture or epiphyseal separation of greater trochanter, a lateral radiograph being necessary for this (Denny *et al.*, 1971).

Carmichael *et al.* (1989) stated that radiographs of stifle in lateral and craniocaudal planes were necessary for diagnosis of distal femoral single condylar fracture in dogs. The lateral condylar fracture was less obvious in lateral views with only a disturbance in the outline of articular surface. The craniocaudal view explained the fracture line, the degree of fragment and joint displacement. Also the lateral view of medial condylar fracture revealed a caudally displaced fragment whereas the craniocaudal view revealed a proximal displacement of the same

Typical ventro-dorsal radiographs of hip usually demonstrated femoral head fracture, but occasionally a frog legged ventro dorsal view was needed to evaluate fracture adequately (Payne, 1993).

Farrow (1982) recommended stress radiography to evaluate possibility of avulsive injury to local growth centers in immature animals, and to detect small fracture fragments.

Radiography was used to confirm fracture diagnosis and to determine fracture configurations to allow for correct decisions, regarding repair of fracture. At least two divergent views of entire affected bone (preferably at 90^0 to one another) were needed to assess fracture configuration accurately and allowed three dimensional modeling of fracture. Radiographs were taken immediately after surgery for assessing the repair and serve for comparison with follow up radiographs (Roush, 2005).

2.19.2. Post operative radiographic evaluation

Sumner-Smith (1974) explained confusing evidence presented in clinically healing fractures which could mislead the clinician, in the light of an investigation done into healing of experimentally induced fractures of radius and ulna in miniature poodles and mongrels. In mongrels with radius and ulna fractured and left unsupported, the fracture was firm at a very early stage but radiographically callus was insufficient to bridge fracture gap. Radiological evidence of healing was that of a mineralized callus and it might be concluded that in these dogs union had occurred by unmineralised osteoid tissue.

Cook *et al.,* (1999) scored final follow up radiograph for fracture healing as: 0-complete radiographic healing, 1-appropriate progression towards healing,but not completely healed radiographically, 2-inappropriate progression toward healing, 3-no evidence of healing,failure.

There was no direct relationship between radiographic change and clinical outcome as observed by Perez-Aparicio and Fjeld (1993) following repair of femoral capital physeal fractures.

Radiographic abnormalities of the femoral head and neck were observed in all dogs which underwent repair of femoral capital physeal fractures. These changes included: degenerative joint disease, deformity or resorption of the femoral head, shortened femoral neck, resorption (apple coring) of femoral neck and subluxation of coxofemoral joint (Gibson *et al.*, 1991).

Fischer *et al.* (2004) evaluated the anatomic reduction and surgical stabilization of femoral capital physeal fractures in cats repaired with K wires. Reduction of the fracture was graded as anatomic reduction (grade 1), good reduction and functional outcome likely (grade 2), malaligned and possibly requires revision (grade 3), unable to achieve adequate reduction (grade 4). Reduction of fracture was graded as 1 or 2 in all except one, but placement of K wires was determined to be unsuitable in 75 per cent cases. Lameness was not observed in 71 per cent cases at four weeks post operative to reveal that less than adequate fracture reduction and K wire placement did not affect the functional outcome of fracture repair. In cases where implants were not removed, lameness attributable to implants was not observed.

Young dogs were more capable of repairing from articular fractures without developing DJD or might be because humeral condylar fractures in young dogs were typically result of low energy trauma. (Guille *et al.*, 2004)

Healing of fractures was assessed from follow up radiographs taken at frequent intervals to evaluate healing. Early signs of healing included a periosteal reaction near the fracture, callus formation at the site, minor resorption and remodeling of fragment ends, incorporation of fragment or bone grafts, primary bridging of a rigidly stable fracture with woven bone etc whereas complete healing could be confirmed by bridging of bone or callus across the fracture lines, disappearance of fracture lines and callus resorption and remodeling (Roush, 2005).

Rovesti *et al.*. (2006) used immediate post operative radiographs to evaluate the degree of fracture reduction and alignment. Contact between fracture fragments and the axial realignment of treated limb were assessed using following scale.

Excellent – 90 – 100 per cent contact between fracture fragments, axial malalignment in any plane less than 5^0.

Good – 50 per cent- 89 per cent contact between fracture fragments, axial malalignment in any plane less than 10^0.

Fair – 10 per cent-49 per cent contact between fracture fragments, axial malalignment in any plane less than 30^0.

Poor – 0 – 9 per cent contact between fracture fragments, axial malalignment in any plane less than 30^0.

2.20. SHORTCOMINGS

7 per cent of physeal fractures resulted in growth deformities of which 90 per cent were type V injury (Marretta and Schrader, 1983).

Tyagi *et al.* (2002) encountered difficulty in fixing olecranon with tension band wiring because of the normal anatomical medial deviation of the proximal part of olecranon, which resulted in frequent slipping and rotation of fragment along with movement of Steinman pins.

Byron *et al.* (2002) opined that the traditional fracture fixation plates were often inadequate for repair of condylar fractures because of limited space in the distal fragment for placement of bone screws. Solutions for this shortcoming had included use of angled blade plates, condylar buttress plates, cobra-head plates, condylar screw plates etc.

Johnson (2003) stated that long oblique fractures could be more difficult to reduce than transverse fractures because the fracture line configuration was inappropriate for bending or levering techniques. Additionally, the muscle contractions not opposed by the fracture surface configuration and overriding occurred even after reduction. The bone segments could be secured with bone holding forceps and the segments distracted to reduce the fracture, but it was often difficult to achieve and maintain anatomical reduction with this approach

Supracondylar fractures involving distal metaphyseal region of femur were common in mature patients. They were difficult to be reduced anatomically because of pull of muscles and distal nature of fracture, and implant system commonly used included pin and wire, lag screws, bone plate, interlocking nails and plate-rod fixation (Beale, 2004).

2.21. COMPLICATIONS

According to Dingwall and Smith (1971) implant failure was a major problem in the repair of avulsion of tibial tubercle.

Culvenor *et al.* (1978) studied the pattern of closure of distal femoral growth plate in dogs following an injury involving the physis. Calcification of the physis, a sign of impending closure was evident radiographically in all dogs at week 4. Also in dogs where normograde pinning was done, had a cartilage deficit in the intercondylar fossa at the point of pin penetration. The signs of growth plate closure were evident histologically even from first post operative week.

According to Whitney and Schrader (1987), the major problem with dynamic cross pinning was distal pin migration (14 per cent) which happened with instability at fracture site. Limb shortening was common in animals with a considerable amount of growth potential at the time of physeal injury.

Gibson *et al.* (1991) reported that performance of Femoral Head and Neck Excision (FHNE) as a second procedure because of complications associated with repair of capital femoral physeal fractures which included femoral neck lysis, collapse of femoral head, disruption of fracture repair, and osteomyelitis.

Pin tract inflammation was the most common complication with predominant affection of the transcondylar pin following repair of humeral condylar fracture using a modified type Ia external fixator (Guerin *et al.*, 1998)

Incidence of pin loosening with external fixator ranged from 16 per cent to 100 per cent (Marcellin-Little, 2003).

Stigen (1999) stated that complications of normograde intra medullary pinning for supra condylar fracture of distal femur in dogs and cats were less (8 %) and included infection, instability and muscle fibrosis.

Common complications associated with repair of femoral capital epiphyseal fracture in cattle using screws and pins included malpositioning of implants (not engaging femoral head, implant penetrating joint space, misalignment of epiphysis) and bending of pin. In one case the pin backed out of epiphyseal fragment in two days following surgical repair (Ewoldt *et al.*, 2003).

Complication rate associated with conservative treatment of distal radius and ulna fracture in small and toy breeds was 75 per cent apparently due to significantly reduced blood supply to distal part of radius in these breeds (Harasen, 2003b).

Fracture malunion, poor joint function, osteoarthritis, and, premature closure of physis in skeletally immature animals were the most common complications of articular and periarticular fractures. Excessive fibrosis or exuberant callus formation might reduce the range of joint movement and might predispose to muscle contracture especially in distal femoral fracture. Non union (exception was distal radius and ulna) and implant failures were less common (Macias and McKee, 2003).

Beale (2004) reported that pin migration and sciatic nerve entrapment occurred with femoral extremity fracture repair. Quadriceps tie-down happened with distal femoral fracture with incorporation of the muscle in extensive bony callus.

Jackson *et al.* (2004) described that fracture malunion could be caused by premature weight bearing following fracture repair, inadequate fixation, or an untreated or improperly treated fracture and resultant nonanatomic position could be functional or nonfunctional, depending on bone and position of healing. Resulting abnormal loading of bone could be detrimental to joint cartilage and lead to joint diseases in adjascent joints and these must be prevented though these were realities of fracture repair

Articular lag screw fixation of femoral capital fracture resulted in unacceptable rate of complications with hip joint laxity, acetabular flattening, osteopenia of femoral neck and fixation failure (Miller and Anderson, 1993).

Distal femoral fractures in immature dogs were prone to develop quadriceps tie down whose correction was difficult or impossible. Distal radial fractures in small breed dogs had a high incidence of non union and should be given rigid plate or external fixator stability. Salter Harris fractures of distal ulnar physis of immature dogs were difficult to diagnose in initial radiographs and often resulted in premature closure of physis and carpal valgus (Roush, 2005).

The increased incidence of screw failure at humeral condyle was due to severely limited availability of bone stock for fixation leading to high levels of strain on the supracondylar fracture line (McCartney *et al.*, 2007).

Voss and Leikovsky (2007) observed that premature closure of radial physis was common in cats following an injury from a fall or jump in contrast to dogs where distal ulna was more prone. This may be because of the conial shape of ulnar physis in dogs which created a compression injury to the physis with any laterally directed force

Parker and Bloomberg, (1984) stated that premature closure of physis normally resulted from naturally occurring canine distal femoral physeal fractures regardless of the type of fixation. The amount of femoral shortening depended on age and growth potential at the time of injury.

2.22. PROGNOSIS

Salter types I and II had excellent prognosis except when physis was intra articular. In the study made on physeal injuries, physeal closure occurred within 4 weeks following all type I and II injuries involving femoral proximal physis regardless of fixation method used (Marretta and Schrader, 1983).

According to Prieur (1989), factors governing the prognosis of physeal injuries were: age, the bone involved, blood supply, damage to the germinal zone, endocrine disorders, osteomyelitis, and accuracy of reduction and stability of fixation. Deformity with partial or complete closure of physis was common with type V fractures, severity of which depended on age of patient and bone damaged

In the absence of mitigating factors, such as comminution at the fracture site or infection, excellent clinical results could be expected following repair of most of the intra articular fractures (Payne, 1993)

Johnson *et al*(1994) opined that radiographic classification of a fracture into Salter Harris categories was not always consistent with the histological appearance described by Salter Harris and should not be relied on as an indicator of future physeal function. The prognosis of physeal fracture should be guarded until radiographic evidence of function was obtained at a later date

2.23. HAEMATOLOGY AND SERUM BIOCHEMISTRY

The variation in values of serum calcium and phosphorus levels had no correlation with bone healing, since variations occurred with experimental (dogs with bone fracture) and control (sham operated dogs) animals. A significant rise in serum alkaline phosphatase seen at 7 and 14 days post-surgery in experimental animals was ascribed to fibrous tissue formation that was related to early stages of bone repair (Singh *et al.*, 1976).

In an experimental study, Pandey and Udupa (1981) observed no change in calcium level following fracture of tibia repaired by intra medullary nailing. Serum phosphorus level was significantly high between 5 and 23 days after fracture.

Alkaline phosphatase level was significantly higher between 7 to 20 days post operative following fracture of tibia repaired by intra medullary nailing. Alkaline phosphatase helped in new bone formation and accelerates process of calcium deposition at the area of fracture (Pandey and Udupa, 1981).

Following supra condylar fracture fixation, there was a significant increase in Total Leucocyte Count, with an absolute increase in neutrophils at the expense of lymphocytes, possibly due to normal response of body to trauma and an elevated serum alkaline phosphatase activity from day 1 with an increased osteoblastic activity (Aithal *et al.*, 1998).

Zama *et al.*, (1999) reported a significant increase in neutrophil count and decrease ($p<0.05$) in lymphocyte count on postoperative day one hematology following intra medullary pinning of created femur fractures in goats. No significant changes were noticed in monocyte, eosinophil and basophil counts at different intervals.

Following internal fixation of femur diaphyseal fracture in goats, the serum alkaline phosphatase showed a continous increase upto day 20 post operative which represented an increased osteoblasic/chondroblastic activity (Zama *et al.*, 1999).

A non-significant increase ($P > 0.05$) in serum calcium and inorganic phosphorus was noted in all animals postoperatively after intramedullary pinning of femur fracture in goats (Zama *et al.*, 1999).

Venkateswaralu (2005) observed variations in hemogram following long bone fractures in dogs and according to the author these marginal variations in hemogram might be due to the cellular reaction to trauma during the healing process.

Materials and methods

3. MATERIALS AND METHODS

3.1. SELECTION OF CASES

The study was conducted in twelve clinical cases of dogs with fractures of long bone extremities presented to the surgery units of Veterinary College Hospital, Mannuthy and University Veterinary Hospital, Kokkalai, during the period from February 2007 to June 2008. The fracture of extremity of long bone was confirmed radiographically in each case and those biomechanically unstable fractures requiring internal fixation were selected for the study. The aim of study was to assess the feasibility of various surgical fixation methods in the repair of extremity fractures and to find out the easy, effective and cheaper technique.

3.2. BROAD OUTLINE OF WORK

Dogs selected for the study was subjected to detailed clinical, radiological and haemato-biochemical evaluation to ensure fitness of the animal for the surgery. Fractures were assessed radiographically and based on various biomechanical forces acting on the fracture site, location of fracture, status of physis, activity of the animal, availability of implants, and economy and compliance of owner, the fixation method was selected. Repair was assessed based on immediate post operative radiograph and overall success was evaluated based on clinical, radiographic and haemato-biochemical asessmenrt done fortnightly for a period of 6 weeks or as and when required. Implants were removed on clinical healing or in presence of implant related complications.

3.3. ANAMNESIS

The signalment, anamnesis and symptoms noticed with their duration were recorded as reported by owner.

3.4. PRE – OPERATIVE CONSIDERATIONS

Dogs presented with fracture due to significant trauma were thoroughly evaluated clinically and radiologically to ascertain their fitness. Dogs with spontaneous trauma were assessed for pathological origin. Injuries other than fracture were taken care of and if needed surgery was delayed for stabilizing the patient. Whenever surgery was delayed the fracture was supported by external splints or plaster of Paris cast. All animals were fasted for 12 hours prior to surgery.

3.4.1. Pre operative preparation

The affected limb was shaved from the dorsal midline to hock/knee, scrubbed with povidone iodine scrub solution, washed and mopped dry. For all distracted fractures continous traction was given by suspending the limb on patient's own weight for about 20 minutes (Johnson, 2003) (Fig.2.)

The animal was restrained on contralateral recumbency whenever the approach to fracture was lateral and on ipsilateral or dorsal recumbency when approach was medial (Fig.3.) The limb was draped surgically after painting the surgical site with povidone iodine solution. Vascular access was maintained throughout the surgery by providing intravenous infusion with dextrose-normal saline solution.

3.5. SELECTION OF IMPLANTS

Smooth shanked Steinmannn pins with trocar point on one end and blunt at other end were used. Kirschner wires used were smooth shanked with trocar points on both ends (Fig.1.). Orthopaedic wire used was of monofilament stainless steel type. For intramedullary pinning, Steinmann pins filling 60 to 70 per cent of the diameter of the medullary canal at its narrowest part were selected. For external skeletal fixation, the fixation pins filling 30 per cent of the medullary canal were selected. Kirschner wires used in the study filled 20 per cent of medullary canal width in young dogs and 30 per cent of the same in skeletally mature patients.

3.6. ANAESTHESIA

The surgery was done under general anaesthesia (plane III). Atropine sulphate[1] at the rate of 0.045mg/kg body weight and xylazine hydrochloride[2] at the rate of 1 mg/kg body weight was administered intra muscularly at 10 minute interval, to pre medicate all dogs. Anaesthesia was induced with ketamine hydrochloride[3] intramuscularly at the dose rate of 10mg/kg body weight. Muscle relaxation was achieved through intravenous administration of diazepam[4] at the rate of 0.25mg/kg body weight before application of traction. During surgery anaesthesia was maintained with intravenous administration of xylazine-ketamine mixture (equal volumes) and diazepam to effect.

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[1]Atropine sulphate injection IP. (o.6mg/ml),Mount Mettur Pharmaceuticals Ltd.,India,1ml ampoule

[2]Xylaxin, (20mg/ml), Indian Immunologicals Ltd.,Guntur dist., Andhra Pradesh,2 ml vial

[3]Ketmin 50,(50mg/ml), Themis Medicare Ltd.,Mumbai, 2ml ampoule

[4]Calmpose , (5mg/ml), Ranbaxy laboratories Ltd.,Mumbai, 2ml ampoule

3.7. SURGICAL PROCEDURE

The reduction and immobilization of the fractured bones was accomplished by open and closed methods according to the type of fracture.

3.7.1. Open reduction approaches

3.7.1.1. Proximal femur

The fracture site was approached by a craniolateral incision starting proximal to greater trochanter curving cranially, and extending distally to one quarter of femoral shaft (Plate 1b). After dissecting subcutaneous tissue along same line, incision was made into the fascia lata cranial to greater trochanter and extended distally to allow retraction of biceps femoris caudally and the fascia cranially. Muscular tensor fascia lata was dissected from the fascia of vastus lateralis and middle gluteal muscle to retract gluteal muscle dorsally. Vastus lateralis was elevated from proximal femur to expose extra capsular fracture. The incision through fascia lata was extended proximally through gluteal fascia along cranial border of the superficial gluteal muscle. Blunt dissection along the neck of femur revealed extracapsular neck fracture. Further dissection with lateral retraction of vastus lateralis and vastus intermedius exposed the joint capsule which was incised perpendicular to acetabulum for intracapsular fracture (Piermatei and Greely, 1966).

3.7.1.2. Distal femur

A proximally extended lateral parapatellar incision was utilized for open reduction of distal femoral fractures (Carmichael *et al.*, 1989). A curved parapatellar incision starting from distal fourth of femur, curving cranially parallel to patellar ligament was made, keeping the limb flexed at stifle (Plate 1c). Subcutaneous fat and fascia were incised on same line. Fascia lata was incised proximally along cranial border of biceps femoris, continuing into lateral fascia of stifle joint. Biceps with attached lateral retinaculum was retracted caudally and vastus lateralis cranially after elevating the latter from femoral shaft to expose supracondylar fracture (Fig.5). In cases were intramedullary pin was inserted normograde from distal femur, the joint capsule was also incised (Fig.6).

3.7.1.3. Proximal tibia

A curvilinear incision was placed starting proximally from a point lateral to tibial tuberosity, curving around cranial border of tibial crest and extending medially to proximal third of tibia (Fig.1d).Dissected subcutaneous fascia and fat and elevated anterior tibial muscle to expose proximal tibia. The stifle was kept extended to assist reduction of fracture.

3.7.1.4. Distal humerus

A lateral approach to the distal humerus shaft was utilized to reduce supracondylar fractures (Plate 1a) Through a lateral skin incision along craniolateral border of distal humeral shaft extending to lateral epicondyle, subcutaneous fascia was dissected and deep fascia was incised along cranial border of triceps. Brachialis and brachiocephalicus muscles were separated bluntly and brachiocephalicus along with superficial pectoral muscle was retracted cranially. Brachialis with triceps was retracted caudally to expose distal humerus (Piermatei and Greely, 1966) (Fig. 4).

3.7.2. Closed reduction

The minimally displaced subtrochanteric femoral fracture and distal metaphyseal fractures of radius and ulna were reduced by external manipulation and traction and counter traction.

3.7.3. Fixation methods

3.7.3.1. Proximal femur

Femoral capital physeal separation was fixed using a single K wire (2mm) inserted normograde through fovea capitis directed towards base of neck, and the pin was countersunk below articular cartilage. Undisplaced subtrochanteric fracture in a pup was corrected using closed method of intramedullary pinning using a 2.5mm Steinman pin inserted normograde through trochanteric fossa (Fig.8). Oblique subtrochanteric fracture was stabilized using a 3mm Steinman pin inserted normograde and cerclage wiring using a 20G orthopedic wire. Simple displaced subtrochanteric fracture was repaired with a single intramedullary pin placed retrograde and an antirotational K wire. For subtrochanteric fracture with simultaneous fracture of femoral neck, the subtrochanteric fracture was stabilized with intramedullary Steinman pin inserted retrograde. Crosspinning was done with K wires with one pin inserted from distal to trochanter major, directed towards neck across fracture site to lodge in epiphysis. The second cross pin was done with K wire inserted from caudal cortex across subtrochanteric fracture to lodge in greater trochanter.

3.7.3.2. Distal femur

In all supracondylar fractures primary fixation was accomplished by Steinman pin inserted retrograde and an antirotational K wire was inserted obliquely from lateral epicondyle across fracture site, to lodge in medial cortex of proximal fragment (Fig.12). In Salter Harris II fracture, the Steinman pin was inserted normograde from distal fragment through intercondyloid fossa, just cranial to cranial cruciate ligament, in a caudal direction to exit at fracture site near caudal cortex, and directed into proximal fragment (after reducing fracture) to exit through trochanteric fossa proximally(Aithal *et al.*, 1998). Additional fixation was done by one or two antirotational cross pins (Fig.9).

3.7.3.3. Proximal tibia

The avulsed tibial tuberosity was secured with a 1.5mm K wire inserted into the fragment to lodge in caudal cortex of proximal tibia. A 20G orthopedic wire was passed through a horizontal hole drilled on the cranial crest about 5cm distal to fracture, which was taken over the K wire in a figure of eight fashion and tightened with a twist knot. The wire knot was bent inwards to the bone surface and the protruding tip of K wire bent upwards (Fig.13). The stability of reduction was checked by flexing and extending the stifle. The proximal tibial metaphyseal fracture was stabilized by cross pinning in a closed method.

3.7.3.4. Distal humerus

The supracondylar fracture was immobilized primarily with a single Steinman pin (3mm) passed retrograde (Fig.10) and rotational stability was provided with an antirotational K wire (2mm) inserted as cross pin from distal and caudal to lateral epicondyle across fracture site to anchor in the medial cortex of humeral shaft proximal to fracture line (Fig.11).

3.7.3.5. Distal radius and ulna fractures

These were reduced by external manipulation following 20 minute traction and were immobilized using a Type I half pin splintage external fixation device applied to radius with four pins (with only one pin in the distal fragment in one case) and a single connecting bar (Fig.15). The proximal and distal pins were inserted first at an angle of 45^0 to 60^0 to the long axis of the bone, from the craniomedial aspect of radius towards caudolateral aspect. A connecting bar with four mini AO clamps was attached and two outer clamps were tightened on the pins. The middle two pins were passed through the clamps and driven into the bone (Fig.14). All clamps were tightened (Carmichael, 1991).

The surgical site was frequently irrigated with gentamicin mixed normal saline solution for all cases underwent open reduction. In all cases with intracapsular fractures the joint capsule was sutured in simple continous fashion using polypropylene sutures. The fascia and muscles were apposed in simple continous fashion using chromic catgut (No.1/0). A continous subcuticular suture was inserted with 1/0 catgut and skin was closed with horizontal mattress sutures using nylon (Fig.16).

3.8. POST OPERATIVE CARE

The suture line was padded with povidone iodine soaked sterile cotton pad. All cases of internal fixation had the limb supported by plaster of Paris cast. Cases of external skeletal fixation had the pin tips covered with cotton secured by adhesive plaster, the pin entry points covered by povidone iodine soaked sterile pads and a soft bandage with thick cotton padding was applied.

Antibiotics were administered for five days post operatively with ceftriaxone sodium[1] at the dose rate of 20mg/kg body weight as intravenous injection on the day of surgery and continued with cephalexin[2] tablets orally on the subsequent days. Post operative analgesia was provided by administration of meloxicam[3] at the rate of 0.5mg/kg body weight whenever needed. Balanced calcium-phosphorus supplementation and diet modifications were recommended for cases with poor bone quality.

The activity of all animals was advised to be restricted for a period of two to four weeks or until signs of clinical healing were evident and on leash walking for next two to three weeks. The case that underwent tension band wiring was advised to be taken for moderate exercise from first week onwards. Passive range of motion exercise was recommended for the case which had undergone excision arthroplasty for femoral head fracture and for cases which showed signs of quadriceps contracture.

Post operative evaluation was carried out at two weeks interval for a period of six weeks and whenever required.

3.9. REMOVAL OF IMPLANTS

Internal fixation implants were removed only in cases which developed implant associated complications. Implants were retained otherwise. External skeletal fixator was removed under sedation following complete healing of fracture. Animals were sedated with xylazine hydrochloride at the rate of 2mg/kg body weight after premedication with atropine sulphate at the rate of 0.045 mg/kg body weight, both given intramuscularly.

3.10. EVALUATION OF STUDY

The efficacy of various fixation techniques on fractures of extremity of long bones, was evaluated by clinical, radiological, and haematobiochemical evaluation done at two weeks interval for six weeks or as and when required in between.

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[1]Safevet, 500mg injection,Dosch pharmaceuticals private Ltd.,Mumbai.

[2]Sporidex AF 375mg tablets, Ranbaxy laboratories Ltd., Gugaon.

[3]Mel-OD 7.5mg tablets, Zy.Cadila pharmaceuticals private Ltd.,

3.10.1. Patient evaluation

3.10.1.1. Clinical evaluation

Animals were evaluated clinically by their general clinical presentation, nature of peripheral lymph nodes, functional limb usage, neurological examinaton (motor, sensory and proprioceptive reflexes), etc. The degree of lameness was scored as per Sumner-Smith scores (Sumner-Smith, 1993). The weight bearing of animals on the injured limb was scored on stance, walk and run (Aithal *et al.*, 1998). The final functional outcome was evaluated and graded (Cook *et al.*, 1999)

3.10.1.2. Physiological parameters

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

3.10.1.3. Haematological evaluation

Blood samples were collected preoperatively and fortnightly for assessing haemoglobin concentration, volume of packed red cell (VPRC), erythrocyte sedimentation rate (ESR), total leucocyte count (TLC), and differential leucocyte count (DLC) (Schalm *et al.*, 2000).

3.10.1.4. Serum biochemical evaluation

Using blood samples collected pre operatively and at two weeks interval, alkaline phosphatase was estimated by kinetic method using serum alkaline phosphatase analysis kit. Serum calcium and phosphorus were estimated by photometric method.

3.10.2. Radiographic evaluation

Orthogonal views of the fractured bones were taken to assess the location, plane, and orientation of fracture. When the fracture involved physis, the other extremity of the same bone or the contralateral bone was radiographed to ascertain the status of physis (open or closed).

Radiographs of the bone were taken immediate postoperatively to assess placement of fixation implants and degree of reduction and alignment. Immediate postoperative reduction was assessed and scored on a scale of 1- 4 (Fischer et al., 2004). Radiographs taken at fortnightly intervals were evaluated for maintenance of reduction and alignment, progress of healing, presence of any complications and implant stability, and for any other changes of bone. and maintenance of reduction was graded according to Rovesti *et al.* (2006) as excellent, good, fair and poor.

3.10.3. Statistical analysis of data

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

Fig. 1. Implants and special instruments used

Fig. 2. Applying traction by gravity

Fig. 3. Draping and positioning limb for surgery

Plate 1. Approaches to bones

a. Lateral approach - Humerus

b. Craniolateral approach
Proximal femur

c. Lateral parapatellar approach (Proximally extended) - Distal femur

d. Lateral approach- Proximal tibia

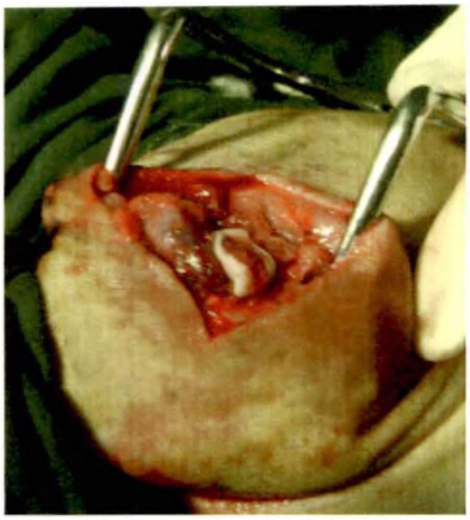

Fig. 4. Exposure of supracondylar fracture - distal humerus

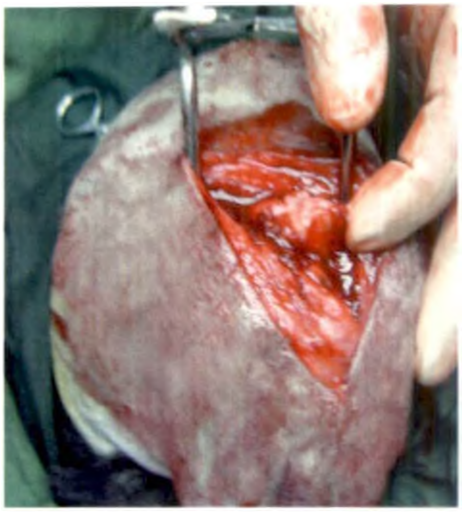

Fig. 5. Exposing the metaphyseal end of fracture fragment in supracondylar femoral fracture

Fig. 6. Exposing the stifle joint for fixation of physeal fracture - Distal femur

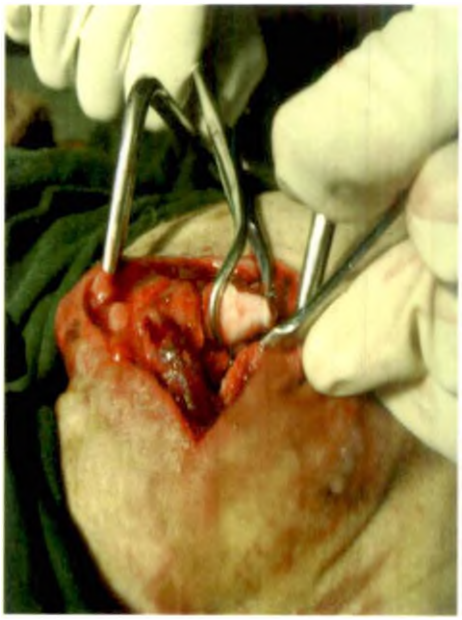

Fig. 7. Reducing fracture with Hohmann's retractor and bone reduction forceps

Fig. 8. Intramedullary pinning of femur in closed method

Fig. 9. Cross pinning from lateral femoral condyle for Salter Harris fracture

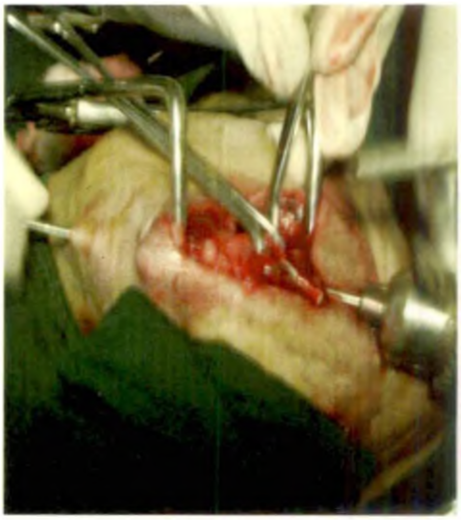

Fig.10. Retrograde pinning of humerus

Fig. 11. Supracondylar humeral fracture reduced excellently with intramedullary pin and cross pin

Fig. 12. Intramedullary pinning with cross pinning in distal femoral fracture

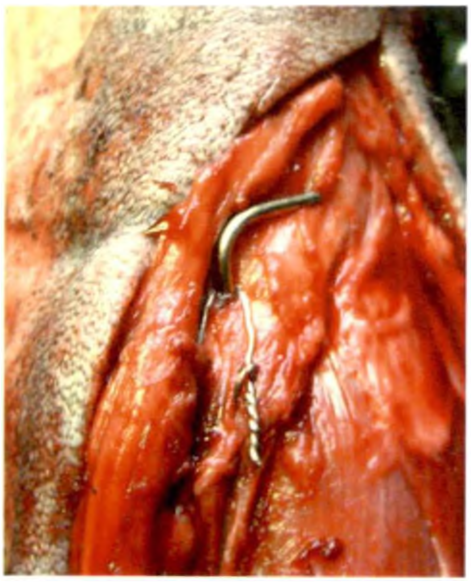

Fig. 13. Tension band wiring of tibial tuberosity

Fig. 14. Drilling fixation pins through preplaced clamps - Radius and ulna fracture

Fig. 15. Type IA External fixation for distal radius and ulna fracture

Fig. 16. Closure of incision

Results

4. RESULTS

The study was conducted to assess the feasibility and efficacy of various management techniques for the repair of fracture of extremity of long bones in dogs. Fourteen dogs with fifteen fractures of extremity of long bones were included in the study.

4.1. INCIDENCE

Dogs presented during the study period, with fracture of long bone extremity came to 40 % of total long bone fractures. Of these, 44.6 % involved femur, 19.6 % affected tibia, and 8.9 % and 26.7% involved humerus and radius-ulna respectively.

4.2. SELECTION OF CASES

Among the dogs with extremity fractures, 14 dogs with 15 fractures were selected for the study and all others were managed conservatively with external coaptation taking into consideration of various factors like age of patient, nature of fracture, quality of bone, financial status and compliance of owner etc. These cases are represented by serial numbers 1 to 14 and fractures represented as F1 to F5 for proximal femoral fracture, F6 to F10 for distal femoral fracture, T1 and T2 for tibial fracture, H for humerus fracture, and R1 and R2 for radius-ulna fracture.

4.3. SIGNALMENT

The average age of incidence was 15.1 months (range: 4 – 36 months), with almost equal incidence in the age groups; ≤ five months, five-twelve months and ≥ twelve months of age. 64 per cent of cases were juveniles (< one year old). All dogs with proximal femoral fractures were more than eight months old (skeletally mature).

Breeds of dogs included in the study were, Great Dane (3), Dachshund (2), Dachshund cross (2), Labrador (2), Pomeranian (1), Spitz (1), German Shepherd Dog (1), Rottweiler (1), and Dobermann (1). Thus five were small breeds; two medium sized breeds and seven were large breed dogs.

Dogs included in the study had body weights ranging from 3.6 kg to 30 kg (average: 16.2 kg). They came in almost equal distribution in the classes with < 10 kg, 10 – 20 kg and >20 kg. body weight.

4.4. ETIOLOGY OF FRACTURES

The exciting causes of fractures were road traffic accident (3), fall from a height (8) and unknown cause with three cases. Two dogs sustained fracture with minimum trauma (fall from a height < 1m) and were later clinically diagnosed as pathological fractures sequel to nutritional imbalance. Two dogs with unknown etiology were considered to have fracture with minimum trauma based on the fact that they were confined when fracture occurred. Details of patient data and anamnesis were presented in Table 1.

4.5. PATTERN OF FRACTURES

Among the fifteen extremity fractures, five were proximal femoral, five were distal femoral, two were proximal tibial, one was distal humeral and two were distal radius-ulna fractures. Twelve of the fifteen fractures involved hind limbs and eight affected left limbs.

The types of fractures encountered in femur were subcapital fracture, subtrochanteric fracture, subtrochanteric fracture with concomitant basilar neck fracture, supracondylar fracture, and Salter Harris type II fracture of distal physis. Avulsion of anterior tibial tuberosity with concomitant displacement of tibial plateau and fracture of proximal metaphysis were the two tibial fractures. Supracondylar fracture of humerus and distal metaphyseal radius-ulna fracture were the fractures of forelimb studied. Articular fractures came to 40 per cent of extremity fractures. Other details of fracture configuration are presented in Table 2. Physis of the fractured extremity was open in seven dogs at the time of sustaining fracture.

The latency of fracture reduction ranged from two to six days.

4.6. SELECTION OF MANAGEMENT TECHNIQUE

The technique for fracture fixation was selected based on the location and configuration of fracture, age and activity of patient, concurrent injuries or diseases, fracture biomechanics, implants available and the financial status and compliance of owner in each case. Management techniques used for each case is given in Table 4. Intramedullary pin being cheaper and easily available was used in various fashions, considering the biomechanics and location of fracture.

4.6.1 Selection of implants

Various pin fixation techniques were used for managing the fractures. In two cases, F2 and T2, 20 G orthopedic wire was used, as cerclage wire in former and tension band wire in latter. Smooth Steinman pins with trocar point were used for intramedullary pinning (IMP), and as transfixation pins in external skeletal fixator frame. For IMP the pin filled 70 per cent of radiographic width of medullary canal of the bone (at the narrowest part). The criteria for selection of Steinmann pin and K wire for using as transfixation pin/ cross pin was that it should not be more than, 30 per cent of diameter of medullary canal of the bone in skeletally mature patients and 20 per cent of medullary canal width in skeletally immature dogs. Implants were found satisfactory for their purpose in their material properties except for the stainless steel 20G wire used as cerclage wire which was broken before bone healing. Smooth pins were satisfactory as intramedullary pin but pin migration was observed with smooth K wires when used in areas of high movement and stress like at proximal femur.

4.7. EVALUATION OF MANAGEMENT TECHNIQUES

4.7.1 Anaesthesia

The surgery was performed under general anaesthesia (plane III). Atropine sulphate at the rate of 0.045mg/kg body weight and xylazine hydrochloride at the rate of 1 mg/kg body weight was administered intra muscularly at a 10 minute interval, to premedicate all dogs. Anaesthesia was induced with ketamine hydrochloride intramuscularly at the dose rate of 10mg/kg body weight. Muscle relaxation was achieved through intravenous administration of diazepam at the rate of 0.25mg/kg body weight before application of traction. During surgery anaesthesia was maintained with intravenous administration of xylazine-ketamine mixture and diazepam to effect. The level anaesthesia and muscle relaxation was satisfactory through out the procedure.

4.7.2. Application of traction

Traction applied on the limb by gravity for 20 minutes in all displaced fractures under general anaesthesia proved excellent in bringing adequate muscle fatigue and relaxation to assist fracture reduction.

4.7.3. Surgical exposure

The surgical approach used for various fractures were critically evaluated for technical easiness, soft tissue trauma, surgical haemorrhage, exposure of bone etc.

The craniolateral approach to proximal femur was satisfactory for minimally displaced subtrochanteric fracture and subcapital fracture with hip dislocation. For severely displaced sub trochanteric fracture, the approach necessitated blunt dissection of gluteal muscles. The exposure of femoral neck was inadequate as well as assessment of anatomical orientation of the proximal fragment was difficult with the craniolateral incision alone. The lateral approach chosen for avulsed tibial tuberosity was satisfactory for tension band wiring. However the incision was extended curving craniad for exposing tibial crest for passing the tension band wire.

Lateral parapatellar incision was satisfactory for exposing supracondylar fracture as well as for exposing joint whenever required. The supracondylar fracture of humerus was easily and satisfactorily exposed with the lateral approach.

4.7.4. Reduction of fracture

Fractures F2, T1, R1 and R2 were reduced and stabilised by closed method. All other fractures were stabilised after open reduction.

In all cases undergone open surgery, reduction was accomplished by bringing the larger fragment to the less manageable extremity. Leverage of the displaced fragment using Hohmann's retractor and traction exerted by bone holding forceps together with external manipulation on adjascent joints resulted in reduction of fracture (Fig.7).

Closed reduction was done for minimally distracted fracture in F3 with traction and countertraction. Radius-ulna fractures were reduced with external manipulation after sufficient traction which brought excellent (R1) to satisfactory reduction (R2).

Undistracted fractures, F3 and R1, were reduced with minimal effort whereas severely distracted subtrochanteric fractures, F4 and F5, took greater effort.

4.7.5. Insertion of pins

4.7.5.1. Proximal femur

Normograde insertion of smooth K wire through fovea capitis towards neck provided satisfactory reduction of basicapital femoral fracture. The technique was found easier with a dislocated joint.

Insertion of intramedullary pin in retrograde fashion, for subtrochanteric fracture in F4 and F5 was done with little technical difficulty. Predrilling the metaphysis of distal fragment helped in easier insertion of pin as well as resulted in good reduction. Normograde insertion of intramedullary pin by closed method through trochanteric fossa (F2, F3) was least time consuming but required greater surgical expertise. Insertion of K wire as an additional fixation for subtrochanteric fracture was relatively easy.

Cerclage wiring (F2) was technically difficult without a wire passer in this region with heavy musculature and required stripping of muscle around the fracture.

Inserting a K wire in normograde fashion from base of trochanter to capital epiphysis to support basicapital fracture (Case No.4) was technically difficult, as assessment of depth of insertion of pin in the epiphysis was difficult.

4.7.5.2. Distal femur

Normograde and retrograde insertion of intramedullary pin was found satisfactory to fix distal femoral fracture. Retrograde insertion of pin could be done with metaphyseal fracture which avoided unnecessary opening of joint capsule. Normograde insertion of pin from distal bone from a point cranial to origin of cruciate ligaments was excellent in bringing perfect reduction of fracture as the smaller extremity was compressed to parent bone during insertion of pin, but required surgical skill to direct the pin to emerge proximally through trochanteric fossa. The technique gave maximum purchase of pin in the bone with the pin present at a safer position in the joint. Case Nos. 9 and 10 had osteopenic bone and the intramedullary pins were inserted with little bone resistance.

Insertion of antirotational K wire as cross pin from lateral condyle was relatively easy and less time consuming but care must be taken in distally curved femur to avoid chance of pin getting out of bone in its course. Insertion of double cross pins from medial and lateral surfaces of condyles proximal to articular surfaces required surgical expertise, but provided excellent fixation in F6.

4.7.5.3. Proximal tibia

Avulsion of anterior tibial tuberosity was fixed with tension band wiring which required extensive tissue manipulation and more surgical time but provided excellent reduction and fixation. Single pin was inserted from cranial aspect of tuberosity, driven diagonally to come out of far cortex, to provide good anchorage. Bending the protruding pin proximally over the tuberosity avoided slippage of tension band wire and provided good implant stability. Standard usage of double pin for fixing the fragment in tension band wiring could not be done here since the size of the fragment was too small for a second pin. Insertion of single pin from medial aspect of proximal tibia in a closed manner, across fracture was easy, less time consuming and resulted in minimal tissue trauma.

4.7.5.4. Distal humerus

Retrograde inserted intramedullary pin emerged proximally below the destination point i.e., below greater tubercle. The cross pin from lateral epicondylar crest got deflected at the previously placed intramedullary pin which could be detected only in the post operative radiograph. The technique was easy, inflicted less bone and soft tissue trauma and was less time consuming.

4.7.5.5. Distal radius-ulna

Both cases with distal metaphyseal fracture were fixed in Type IA external skeletal fixation. Insertion of transfixation pins from craniomedial to caudolateral aspect of bone avoided major structures, provided better bone purchase and reduced post operative patient discomfort. The sequence of inserting pins and attaching the connecting bar as described by Carmichael (1991) proved excellent in maintaining reduction through out the procedure. The only difficulty encountered was with inserting the distal pin/pins through the smaller distal fragment, avoiding fracture line proximally and physis distally. The distal pin entered fracture line initially in R2 which was completely withdrawn and reinserted and in the same case only a single pin was passed through distal fragment which could not stand two pins due to smaller size.

4.7.6. Closure of incision

The technique used for closure of joint capsule, apposition of dissected muscle and fascia, and skin incision was satisfactory and no complication was observed with the selected suture materials or suture patterns in process of healing.

4.7.7. External coaptation

For all cases except R1 and R2, the limb was immobilized externally with Plaster of Paris cast which restricted activity of animal, at the same time provided additional support for internal fixation. Casts were removed when 75% fracture gap was radiographically bridged by callus. The cast was self mutilated in Case Nos. 1, 4, 5, and 10 and pressure exerted by cast over achilis tendon resulted in occasional knuckling in Case No.2. Quadriceps contracture was observed in Case Nos. 9 and 10.

Details of the technical feasibility and ease of application of each management technique is presented in Table 8. The average time taken for open reduction (from skin incision to closure of skin) of extremity fracture in the study was 28 minutes and that for closed reduction and fixation was 16.5 minutes. The least time consuming fixation was closed cross pinning of proximal tibial fracture(T1) and closed intramedullary pinning (F3), and most time consuming was tension band wiring (T2) and intramedullary pinning with multiple cross pinning(F4). Surgical time did not cross one hour in any of these cases. Soft tissue trauma was minimum for closed reduction and fixation and among open reduction it was minimum for distal metaphyseal femur fracture repair. Surgical haemorrhage was minimum in F3 and T1 and maximum in F4, F5 and H. Bone trauma with the fixation was minimum in basicapital femoral fracture fixation of F1 and tibial fixation of T1.

4.8. POST OPERATIVE CARE

Post operative analgesia was found satisfactory with Meloxicam @ 0.5 mg/kg body weight as no signs of pain were reported in any case, except in Case No.4 in post operative antibiotic coverage with ceftriaxone was provided to all animals were satiasfactory as infections were not observed in any.

Gauzes and cotton were packed between skin and connecting bar of external fixator and whole apparatus was wrapped in light bandage. Frequent cleaning of pin entry points were not advocated and it resulted in formation of scab that prevented entry of infection.

Restricted activity was advised in all animals for three weeks, followed by leash walking for next three weeks.

4.9. REMOVAL OF IMPLANTS

External fixator was removed in six weeks in Case Nos.13 and 14 following complete radiographic healing of fracture. Intramedullary pin was removed in six weeks due to formation of seroma in Case Nos. 3 and 4. All implants were removed in Case No.4 in eight weeks and excision arthroplasty was conducted. In all other cases implants were not removed and no implant related lameness was observed in any of the cases over a follow up period of six months to eighteen months.

4.10. RADIOGRAPHIC EVALUATION

Plain radiographs of orthogonal views of fractured bone proved satisfactory in evaluating fracture configuration and fragment orientation. Though fracture could be detected from single view in all cases orthogonal view was found essential in assessing spatial relationship between fragments.

The displaced Salter Harris II fracture of distal femur appeared a stable minimally displaced fracture in craniocaudal view in F7. Lateral radiograph of femur in F4 revealed subtrochanteric fracture but failed to expose the femoral neck fracture. Orthogonal views were found necessary to ascertain the correct position of implants in the three dimensional bone as well as to assess angulation of bone in either planes after reduction. In F8 lateral view of femur was essential to detect the protrusion of intramedullary pin distally into the joint and the presence of cross pin out of the bone during its course. Lateral angulation of reduced fracture of femur in F9 was detected only in craniocaudal view.

Follow up radiographs in fortnightly interval was sufficient to assess healing as well as to detect any complications. Presence of intact cast masked the activity of bone in many postoperative radiographs. The six A's i.e., alignment, apposition, angulation, apparatus, activity (fracture gap and callus formation) and architecture (periosteal reaction and osteolysis) were evaluated in all follow up radiographs. Postoperative reduction was graded according to Rovesti et *al.* (2006) as excellent, good, fair, and poor. Details are presented in Table 7.

Immediate postoperative reduction was scored on a scale of 1 to 4. (Fischer *et al.*, 2004) and is presented in Table 8.

4.10.1 Radiographic changes

Craniodorsally dislocated hip joint with basicapital fracture of femur (F1) (Plate2a) had the fracture reduced and dislocation corrected satisfactorily in immediate postoperative radiograph (Plate2b). The fracture was found healing with little periosteal callus in follow up radiographs, but the dislocation recurred (Plate2c). Progressive narrowing of femoral neck was observed in these radiographs (Plate 2d). Severely distorted proximal femur forming pseudoarthrosis and a dramatic change in position of K wire was observed in a late follow up radiograph (Fig.20).

The radiographs of long oblique subtrochanteric fracture (F2), immobilized with intramedullary pin and cerclage wire showed malaligned fragments with less than 20 per cent apposition and breakage of cerclage wire in two weeks. The reduction was maintained and the fracture healed with heavy callus in six weeks (Plates 3a and 3b). Minimally displaced subtrochanteric fracture (F3) was maintained in excellent reduction with intramedullary pin and fracture healed with little periosteal callus in four weeks (Plates 3c and 3d).

Subtrochanteric fracture with concomitant basicapital fracture (F4) showed good apposition and alignment until two weeks. The fourth week radiograph showed fixation failure of basicapital fracture with migration of K wire. Severe migration of K wire (that immobilized subtrochanteric fracture) completely out of bone did not affect the stability of fracture reduction. Marked osteolysis and mottling of femoral head and proximal femur was observed in six weeks. Radiograph taken one week after excision arthroplasty showed signs of formation of pseudoarthrosis (Fig.19).

Subtrochanteric fracture (F5), was reduced and fixed satisfactorily with intramedullary pin and cross pin but the animal sustained a second fracture at femoral neck which was detected in second week follow up radiographs (Fig.17). The case was not available for further radiographic follow up.

Salter Harris type II fracture with caudomedial projection remaining with epiphysis (F6 and F7), were reduced and immobilized with intramedullary pin and two cross pins in F6 and with single cross pin in F7. Both the fractures healed completely in six weeks and comparatively less callus formation

formation were observed in F7. Supracondylar fracture in F8 was reduced with slight gap but the fracture showed appropriate progression to healing in four weeks (Plate 4).

Supracondylar fracture of distal femur in osteopenic bones (F9 and F10) was reduced with slight over reduction and both fractures healed with extensive callus formation (Fig.18). The bone was found disfigured with straightened distal extremity.

Transverse proximal metaphyseal fracture of tibia healed in four weeks following excellent reduction and immobilization with single cross pin. Avulsion of tibial tuberosity with separation of proximal epiphysis of tibia was excellently reduced and immobilized with tension band wiring of tibial tuberosity. The fracture gap was found progressively decreasing in follow up radiographs with development of callus and dynamic compression exerted by tension band wiring. The fracture healed completely in six weeks (Plate 5).

The supracondylar fracture of distal humerus was immobilized with slight over reduction and the fracture gap was almost completely bridged by callus in six weeks (Plate 6).

Both the distal radius and ulna fractures showed complete healing in six weeks with little periosteal callus (Plate7). Moderate periosteal reaction was observed in R1 and malalignment in R2 was corrected by callus formation and remodeling. Closure of distal ulnar physis with valgus deformity of radius was observed in R2 from four weeks.

Physis was closed in all seven bones, which had open physis at time of occurance of fracture, in a period of six weeks. Femoral head and neck osteolysis was observed in both intracapsular proximal femoral fractures which had radiographic follow up. Callus formation was extensive in both cases suspected of nutritional hyperparathyroidism. Except for complications with Case Nos. 4 and 5, all other extremity fractures were radiographically healed in six weeks.

4.10.2. Implant evaluation

Single K wire was found successful for its purpose of maintaining reduction of subcapital fracture till healing. However the implant was found severely deflected in direction with necrosis of femoral head and resorption of neck. Intramedullary pin alone could maintain the undisplaced subtrochanteric fracture in reduction and an uneventful healing was observed in F3 with little periosteal callus. Failure to achieve good reduction and healing in F2 happened with faulty intramedullary pinning and breakage of cerclage wire. Subtrochanteric fracture was held in reduction with intramedullary pin and a cross pin in F4 and F5. Cross pin migrated completely out of bone in four weeks in F4 but did not affect stability of reduction. The pin was bent proximally in F5 and did not migrate distally. Fracture of femoral neck was retained in F4 in four weeks post operative, which happened with migration of K wire from capital epiphysis.

Intramedullary pin and double cross pinning with K wires maintained reduction of Salter Harris type II fracture in F6 till complete healing. Intramedullary pin with single cross pin was excellent for the same fracture in F7, where fracture healed with endosteal callus, and satisfactory in maintaining reduction of distal humeral supracondylar fracture in H. Intramedullary pin alone and in combination with cross pin was satisfactory in maintaining reduction of distal femoral metaphyseal fracture in F10 and F9 respectively. .

Tension band wiring brought excellent reduction and healing of avulsed tibial tuberosity in T2 and single cross pin assisted healing of proximal tibial fracture in T1. Type IA external skeletal fixator kept distal metaphyseal fracture of radius and ulna in reduction till healing and thus proved to be satisfactory for the same.

4.11. CLINICAL EVALUATION

4.11.1. Patient evaluation

4.11.1.1. General clinical condition

Case Nos. 4 and 9 were dull and depressed on the day of presentation. Case No.4 had pyrexia and severe extensive contusion of the fractured limb whereas Case No.9 was recumbent with bilateral fracture and had osteopenic bones (Fig.21). All other cases were active and alert throughout observation period.

4.11.1.2. Peripheral lymph nodes

Peripheral lymph nodes were normal in size through out observation period in all dogs except for Case No.4 which had slightly enlarged popliteal lymph nodes.

4.11.1.3. Physiological parameters

All animals included in the study had normal physiological parameters through out the study. A slightly elevated temperature was observed in Case No.4. Details are presented in Table 9.

4.11.1.4. Systemic disturbances

Except for microfilariasis (+++) in Case No.4 and nutritional secondary hyperparathyroidism (as tentatively diagnosed from dietary history, radiographic appearance of bone and fracture and serum biochemistry) in Case

Nos. 9 and 10. No other systemic disease was encountered with any of the animals included in the study. Microfilariasis was treated successfully with levamisole[1] @ 7.5 mg/kg body weight for 7 days in Case No.4, and in Case Nos. 9 and 10 radio density of bone improved with dietary corrections and weekly systemic administration of Calcium[2] and Vitamin D_3[3].

4.11.1.5 Concurrent injuries

Case No.1 had hip dislocation with torn off joint capsule and teres ligament, which was corrected during open reduction of fracture, and a lacerated wound on right abdominal wall which was apposed with sutures and healed in a week. Case No.7 had ipsilateral metacarpal fracture which was immobilized with external coaptation. Case No.9 had fractures of right femur(F9) and left tibia(T1), both included in study, on the day of presentation and found to have sustained a third fracture of right tibial shaft on second week which was immmobilised by external coaptation. Case No.13 had fracture of horizontal ramus of left mandible which was fixed on the day of presentation with K wire and healed in four weeks.

4.11.1.6 Neurological examination

Conscious proprioception of the affected limb was abolished in Case Nos. 13 and 14 and sluggish in Case Nos. 4 and 12 on the day of presentation. The reflex was sluggish during second week evaluation in Case No. 2 and absent in Case No.13. Pedal reflex was sluggish pre operatively in Case Nos. 4 and 12. Neurological status was otherwise normal in all dogs through out observation. Further details are presented in Table 3

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[1]Helmonil 150 mg tablets, Alved pharmaceuticals Ltd.
[2]Calcium Sandoz 10% injection, Novartis India Ltd., Thane.
[3]Arachitol 6l injection, Solvay Pharma India Ltd. Ahmedabad.

4.11.1.7. Clinical signs

Clinical signs of fracture exhibited by each patient was graded and is demonstrated in Table 3. Presence of pain at fracture site, crepitus, edema and abnormal mobility were assessed pre operatively and graded as absent, mild, moderate and severe. Pain and crepitus was observed in all cases except in T2 where crepitus was not significantly appreciated. Edema was absent only in F3, F9 and T1. Abnormal mobility at fracture site was well appreciated only in fore limb fractures. Evaluation of post operative inflammation and pain could not be done in those with intact plaster cast. Pain on manipulation of joint adjacent to fracture was observed up to fourth post operative week in almost all cases. Post operative inflammation at surgical site was observed only in F4.

4.11.1.8. Functional limb usage

The weight bearing on the limb was assessed and scored at different levels (i.e. standing, walking and running), pre operatively and at follow up visits according to Aithal *et al.* (1998). The results are given in Table 5.

Pre operative weight bearing score was 0 in all fore limb fractures, <5 in proximal femoral fracture, and < 6 for distal femoral fractures. The limb usage score improved progressively through out observation period to reach a score ≥9 in all cases except for Case No.4. (Plates 8 and 9).

Lameness evaluation (Sumner Smith, 1993) showed a score above eight preoperatively, which showed progressive improvement to a score ≥ 2 in all cases except in Case No.4. In Case No.4, the limb usage improved after excision arthroplasty.

Final functional outcome as with telephone conversation was graded as 0 to 5 (Cook *et al.*, 1999) and is presented in Table 8. The final functional outcome was more than 2 only in Case Nos. 4 and 10 of which the former had pseudoarthosis of the hip joint and the latter had quadriceps contracture.

4.12. HAEMATOLOGICAL EVALUATION

Blood samples were collected preoperatively and on the fortnightly follow ups for assessing Haemoglobin concentration, Volume of packed red cell (VPRC), Erythrocyte sedimentation rate (ESR), Total leukocyte count (TLC), and Differential leukocyte count (DLC). All the parameters were within the normal range (Table 10). Hemoglobin concentration, and VPRC showed a significant decrease in the first two weeks and ESR showed a significant decrease through out the observation.

4.13. SERUM BIOCHEMICAL EVALUATION

Serum calcium level significantly decreased up to four weeks and then showed a significant increase. Serum phosphorus showed no significant variation through out the observation period. Serum alkaline phosphatase showed significant increase in first two weeks and then showed progressive significant decline. The level of the enzyme remained slightly greater than normal through out the observation period. Details are presented in Table 10.

4.14. COMPLICATIONS

Basicapital femoral fracture started healing with endosteal callus but avascular necrosis of femoral head and resorption of neck together with dislocated hip resulted in pseudoarthrosis in Case No.1. Poorly aligned fracture with 50 per cent end to end apposition in Case No.2 underwent malunion but did not spare the functional limb use or gait. Failure of fixation of femoral neck fracture in Case No.4 together with the necrotic changes of the femoral head and osteolysis of femoral proximal metaphysis, affected the functional limb use seriously (Fig.28). Fracture and separation of femoral head was observed in Case No.5 in second week follow up examination. Quadriceps contracture was observed in Case Nos. 9 and 10 from fourth week (Fig.30). Formation of seroma over protruding pin tip was observed in Case Nos. 2, 4, and 12. Premature closure of ulnar physis resulted in valgus deformity of radius in Case No.13 (Fig.31).

4.14.1 Management of complications

Re-luxation of hip joint in Case No.1 was corrected by closed method and the limb was supported in an Ehmer sling but failed to maintain reduction. Pseudoarthrosis was formed on the joint but did not affect normal gait of animal (Fig.29). Rotational instability created by broken cerclage wire was managed to some extend with butterfly cast and strict cage rest till the fracture healed. Quadriceps contracture was managed in the early stages with passive range of motion exercises in Case No.10; but in Case No.9 the condition could not be managed successfully.

For fracture of femoral neck in Case No.5, conservative management with butterfly cast was chosen due to bad owner compliance. Re fracture of femoral neck in Case No.4 and development of avascular necrosis of femoral head and neck was managed with excision arthroplasty. The animal was reported to have improved in the limb usage after surgery. Seroma formation was observed before adequate healing of fracture in Case No.12 and hence the seroma was drained and bandaged. For Case Nos. 2 and 4, the pin was removed and the condition resolved.

Table 1: Anamnesis of cases studied[1]

Case no.	Breed	Age in months	Sex	Weight (in kg.)	Exciting cause	Nature of trauma	Fracture details		
							Limb	Bone	Type
1	Labrador	8	F	21.5	RTA	Major	L	F	Subcapital
2	Dachshund Cross	15	M	8	Fall from terrace	Major	L	F	Subtrochanteric
3	Dachshund	24	M	12.5	RTA	Major	L	F	Subtrochanteric
4	Great Dane	36	F	30	Unknown	Unknown	R	F	Subtrochanteric+basilar neck
5	Dobermann	12	M	25	Unknown	Minor	R	F	Subtrochanteric
6	Labrador	5	M	23	Fall from a height	Major	L	F	Salter Harris II
7	Dachshund cross	5	F	4	Fall from terrace	Major	L	F	Salter Harris II
8	Pomeranian	15	M	8.5	Fall from terrace	Major	R	F	Supracondylar
9	Great Dane	4	F	12	Fall from cage	Minor	R,L	F,T	Supracondylar, Proximal metaphyseal
10	German Shepherd Dog	5	F	18	Fall from cage	Minor	R	F	Supracondylar
11	Rottweiler	5	M	28.5	Unknown	Minor	L	T	Avulsion of tibial tuberosity with separation of epiphysis
12	Dachshund	8	F	9	RTA	Major	L	H	Supracondylar
13	Great Dane	4	M	19	Fall into well	Major	R	RU	Distal metaphyseal
14	Spitz	6	F	8	Fall from owner's hands	Minor	R	RU	Distal metaphyseal

M – Male F – Female RTA – Road Traffic Accident L – Left R – Right F – Femur T – Tibia H – Humerus RU- Radius and ulna

[1]Table 2: Details of fractures studied

Fr.No.	Extremity affected			Type of fracture	Fracture line	Fracture type	Spatial relation of fragments
	Bone	Area	Region				
F1	Femur	P	M	SC	L shaped,	Basicapital	Minimaly displaced
F2	Femur	P	M	SC	Long oblique	Subtrochanteric	Overriding
F3	Femur	P	M	SC	Transverse	Subtrochanteric	Minimally displaced
F4	Femur	P	M,M	MC	Short oblique,Transverse	Subtrochanteric, Basilar neck	Overriding & distracted
F5	Femur	P	M	SC	Transverse	Subtrochanteric	Overriding & distracted
F6	Femur	D	M+P	SC	Short oblique	Salter Harris II	Moderately displaced
F7	Femur	D	M+P	SC	Short oblique	Salter Harris II	Moderately displaced
F8	Femur	D	M	SC	Transverse	Supracondylar	Moderately displaced
F9	Femur	D	M	SC	Short oblique	Supracondylar	Moderately displaced
F10	Femur	D	M	SC	Short oblique	Supracondylar	Moderately displaced
T1	Tibia	P	M	SC	Transverse	Proximal metaphyseal	Minimally displaced
T2	Tibia	P	P,P	MC	Transverse, Transverse	Avulsion of tibial tuberosity, Separation of tibial plateau	Distracted
H	Humerus	D	M	SC	Short oblique	Supracondylar	Moderately displaced
R1	Radius and ulna	D	M	SC	Short oblique	Distal metaphyseal	Minimally displaced
R2	Radius and ulna	D	M	SC	Short oblique	Distal metaphyseal	Moderately displaced

[1] Fr.No : fracture number P : proximal M : metaphysis SC : single, closed
D : distal P : physis MC : multiple, closed

[1]Table 3 : Clinical signs recorded

Weeks	Pain	Crepitus	Edema	AM	CP	PR	Pain	Crepitus	Edema	A.M	CP	PR	Pain	Crepitus	Edema	AM	CP	PR
	F1						F6						T1					
0	++	++	+	-	N	N	++	++	+	-	N	N	+	+	-	-	N	N
2	+	+	-	-	N	N	+	-	-	-	N	N	+	-	-	-	N	N
4	+	+	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
6	-	+	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
	F2						F7						T2					
0	++	++	++	-	N	N	++	++	+	-	N	N	+	-	-	-	N	N
2	+	+	-	-	S	N	+	-	-	-	N	N	+	-	-	-	N	N
4	+	+	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
6	-	-	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
	F3						F8						H					
0	+	+	-	-	N	N	++	++	+	-	N	N	++	++	++	+	S	S
2	-	-	-	-	N	N	+	-	-	-	N	N	+	-	+	-	N	N
4	-	-	-	-	N	N	-	-	-	-	N	N	+	-	-	-	N	N
6	-	-	-	-	N	N	*	*	*	*	*	*	-	-	-	-	N	N
	F4						F9						R1					
0	++	++	+	-	S	S	+	++	-	-	#	N	++	++	+	+	-	N
2	++	+	+	-	N	N	+	-	-	-	#	N	+	-	+	-	S	N
4	+	+	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
6	+	+	-	-	N	N	-	-	-	-	N	N	-	-	-	-	N	N
	F5						F10						R2					
0	++	++	+	-	N	N	++	++	+	-	N	N	++	++	++	+	-	N
2	+	+	-	-	N	N	+	-	-	-	N	N	+	-	-	-	N	N
4	*	*	*	*	*	*	-	-	-	-	N	N	+	-	-	-	N	N
6	*	*	*	*	*	*	-	-	-	-	N	N	-	-	-	-	N	N

[1] AM : Abnormal Mobility CP : Conscious Proprioception PR : Pedal Reflex * : Not available # : recumbency
+ : slight degree ++ : moderate degree - : Absent S : Sluggish N : Normal F1-10, T1-2, H, R1-2 : Fracture numbers

[1]Table 4: Selection of fixation techniques

Fr..No	Fracture details			Possible fracture biomechanics	Status of physis	Activity level of patient	Owner compliance	Other factors	Fixation adopted
	Bone	Location	Pattern						
F1	Femur	Basicapital	L shaped	Shear	X	++	Fair	Dislocated hip	Single K wire
F2	Femur	Subtrochanteric	Long oblique	Shear+Compression	X	++	Fair	Nil	IMP+Cerclege wiring
F3	Femur	Subtrochanteric	Transverse	Shear+Compression	X	+	Fair	Nil	IMP
F4	Femur	Subtrochanteric , basilar neck	Short oblique , transverse	Shear+Compression, Shear	X	+	Good	Nil	IMP+Multiple cross pins
F5	Femur	Subtrochanteric	Transverse	Shear+Compression	X	++	Fair	Nil	IMP+cross pin
F6	Femur	Salter Harris II	Short oblique	Shear+Compression	-	++	Good	Nil	IMP + cross pin
F7	Femur	Salter Harris II	Short oblique	Shear+Compression	-	++	Good	Ipsilateral metacarpal fracture	IMP+cross pin
F8	Femur	Supracondylar	Transverse	Shear+Compression	X	++	Fair	Nil	IMP+cross pin
F9	Femur	Supracondylar	Short oblique	Shear+Compression	-	++	Fair	Osteopenic bone, Contralateral tibial fracture	IMP+cross pin
F10	Femur	Supracondylar	Short oblique	Shear+Compression	-	+	Fair	Osteopenic bone	IMP
T1	Tibia	Proximal metaphyseal	Transverse	Shear+Compression	-	++	Fair	Osteopenic bone, Contralateral femoral fracture	Single K wire
T2	Tibia	Tibial tuberosity	Transverse	Tension	-	++	Good	Nil	TBW
H	Humerus	Supracondylar	Short oblique	Shear+Compression	X	++	Fair	Nil	IMP+cross pin
R1	Radius and ulna	Distal metaphyseal	Short oblique	Compression	-	+	Good	Nil	ESF IA
R2	Radius and ulna	Distal metaphyseal	Short oblique	Shear+Compression	X	++	Good	Toy breed	ESF IA

[1]Fr.No. : Fracture number X : Closed physis - : open physis + : moderately active ++ : highly active

IMP : Intramedullary pin CP : Cross pin TBW : Tension Band Wiring ESF IA : External skeletal fixation type IA

Table 5 : *Weight bearing score of fractured limb[1]

Case no	Fr. No	weeks	stance	Walk	Run	Total	case No.	Fr. No	weeks	Stance	Walk	Ru n	Tota l	Case no.	Fr. No	weeks	Stance	Walk	Run	Total
1	F1	0	1	2	1	4	6	F6	0	1	3	2	6	9	T1	0	0	0	0	0
		2	2	3	2	7			2	2	3	3	8			2	0	0	0	0
		4	2	4	3	9			4	2	4	4	10			4	2	3	3	8
		6	2	4	3	9			6	2	4	4	10			6	2	4	4	10
2	F2	0	0	1	0	1	7	F7	0	1	3	2	6	11	T2	0	1	3	2	6
		2	2	3	2	7			2	2	3	3	8			2	2	3	3	8
		4	2	3	3	8			4	2	4	3	9			4	2	4	3	9
		6	2	4	3	9			6	2	4	4	10			6	2	4	4	10
3	F3	0	0	2	3	5	8	F8	0	1	2	1	4	12	H	0	0	0	0	0
		2	2	4	3	9			2	2	3	3	8			2	2	3	2	7
		4	2	4	4	10			4	2	4	4	10			4	2	3	3	8
		6	2	4	4	10			6	2	4	4	10			6	2	4	4	10
4	F4	0	1	2	1	4	9	F9	0	0	0	0	0	13	R1	0	0	0	0	0
		2	1	2	2	5			2	0	0	0	0			2	2	3	2	7
		4	1	2	2	5			4	2	3	3	8			4	2	3	3	8
		6	2	3	2	7			6	2	4	3	9			6	2	4	3	9
5	F5	0	1	2	2	5	F	F10	0	1	2	1	4	14	R2	0	0	0	0	0
		2	1	2	2	5			2	1	3	2	7			2	2	3	2	7
		4	1	2	2	5			4	2	3	3	8			4	2	4	3	9
		6	2	3	3	8			6	2	4	4	10			6	2	4	3	9

Fr.no- fracture number

[1] *weight bearing score (Aithal et al., 1998) On stance as 0 – Carrying the limb
1 – Touching the toe
2 – *Touching the paw*

On walk and run as : 0 – Carrying the limb
1 – Occasional touching of toe/paw
2 – *frequent touching of toe/paw*
3 – touching paw in every step partial weight bearing
4 – touching paw in every step with complete weight bearing

Table 6 : Lameness evaluation

Case.Number	Day of observation				Time Of Close To Normal Gait
	Zero week	II week	IV week	VI week	
1	8	4	2	2	IV week
2	10	4	4	2	VI week
3	10	2	0	0	II week
4	9	9	8	8	After excision arthroplasty
5	9	9	*	*	After 2 months
6	8	4	0	0	IV week
7	8	4	0	0	IV week
8	8	4	0	0	IV week
9	10	10	4	2	VI week
10	8	4	4	0	VI week
11	8	4	2	0	IV week
12	10	4	3	0	VI week
13	10	4	3	1	VI week
14	10	4	2	1	IV week

Score according to 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 – Obvoius 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 the toe when standing, carries limb when trotting
10 – Unable to put the foot on the ground
* - not available

[1]Table 7 : Postoperative radiographic evaluation of fractures studied

Fr. No	ALIGNMENT				APPOSITION				ANGULATION				ACTIVITY(CALLUS)						ARCHITECTURE					
													PERIOSTEAL			ENDOSTEAL			PERIOSTEAL			OSTEOLYSIS		
	PO	II	IV	VI	PO	II	IV	VI	PO	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI	II	IV	VI
FI	E	E	E	E	E	E	E	E	-	-	-	-	-	-	-	+	+	+	-	-	-	-	+	+
F2	P	P	P	P	P	P	P	P	+	+	+	+	-	+	+	+	+	+	-	-	-	-	-	-
F3	E	E	E	E	E	E	E	E	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-
F4	E	E	E	E	E	E	E	E	-	-	-	-	+	+	++	-	+	+	-	+	+	-	+	++
	G	G	A	A	G	G	A	A	-	-	A	A	+	A	A	+	A	A	-	+	+	-	+	++
F5	G	G	*	*	G	G	*	*	-	-	*	*	+	*	*	+	*	*	-	*	*	-	*	*
F6	E	E	E	E	E	E	E	E	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-
F7	E	E	E	E	E	E	E	E	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-
F8	E	E	E	*	E	E	E	*	-	-	-	*	+	+	*	+	+	*	-	-	*	-	-	*
F9	E	E	E	E	E	E	E	E	+	+	+	+	+	+	+	+	+	+	++	++	+	-	-	-
F10	E	E	E	E	E	E	E	E	-	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-
T1	E	E	E	E	E	E	E	E	-	+	+	-	-	-	+	+	+	-	-	-	-	-	-	-
T2	E	E	E	E	E	E	E	E	-	-	-	+	+	+	-	+	+	-	-	-	-	-	-	-
H	E	E	E	E	E	E	E	E	-	-	-	-	+	+	+	-	+	+	-	-	-	-	-	-
R1	E	E	E	E	E	E	E	E	-	-	-	-	+	-	-	+	+	+	+	++	++	+	+	+
R2	F	F	F	F	F	F	F	F	+	+	+	+	+	+	+	-	+	+	-	-	-	-	+	+

PO : Post operative IV: Fourth week E : Excellent F : Fair A : Failure of fixation + : Present ++ : Degree of severity
II : Second week VI: Sixth week G : Good P : Poor * : Not available - : Absent

Score of fracture reduction (Rovesti *et al.*, 2006): Excellent – 90 – 100% contact between fracture fragments, axial malalignment in any plane less than5^0.
Good – 50%- 89% contact between fracture fragments, axial malalignment in any plane less than 10^0.
Fair – 10%-49% contact between fracture fragments, axial malalignment in any plane less than 30^0.
Poor – 0 - 9% contact between fracture fragments, axial malalignment in any plane less than 30^0.

[1] Table 8: Evaluation of techniques adopted

Fr. No.	Type of fracture	Exposure	Fixation adopted	TTI	Bone trauma	Soft tissue manipulation	Surgical haemorrhage	*BRS	#FO
F1	Basicapital	Cranio-lateral	Single K wire	1	minimal	severe	moderate	1	1
F2	Subtrochanteric	Cranio-lateral	IMP+Cerclage wire	14	moderate	moderate	minimal	3	1
F3	Subtrochanteric	Nil	IMP	3	moderate	minimal	nil	1	0
F4	Subtrochanteric + Basilar neck	Cranio-lateral	IMP+Multiple K wires	23	moderate	severe	moderate	2	3
F5	Subtrochanteric	Cranio-lateral	IMP+Cross pin	13	moderate	severe	moderate	1	2
F6	Salter Harris II	Lateral parapatellar	IMP+ Cross pins	15	moderate	moderate	moderate	1	0
F7	Salter Harris II	Lateral parapatellar	IMP+Cross pin	7	moderate	moderate	moderate	1	0
F8	Supracondylar	Lateral parapatellar	IMP+Cross pin	13	moderate	moderate	moderate	2	0
F9	Supracondylar	Lateral parapatellar	IMP+Cross pin	8	moderate	moderate	moderate	2	3
F10	Supracondylar	Lateral parapatellar	IMP+Cross pin	4	moderate	moderate	moderate	1	1
T1	Proximal metaphyseal	Nil	Single K wire	1	minimal	moderate	nil	1	0
T2	Avulsion of tuberosity	Lateral	TBW	32	moderate	severe	moderate	1	0
H	Supracondylar	Lateral	IMP+Cross pin	20	moderate	moderate	moderate	2	0
R1	Distal metaphyseal	Nil	ESF I A	32	severe	minimal	minimal	1	2
R2	Distal metaphyseal	Nil	ESF IA	18	severe	minimal	minimal	2	0

[1] Fr. no: Fracture number TTI : Time taken to place implants in minutes BRS : postoperative bone reduction score FO: Functional outcome
IMP : Intramedullary pin TBW : Tension band wiring ESF IA : External skeletal fixation type IA

#functional outcome score (Cook *et al.*, 1999);
0 : No observable lameness
1 : Intermittent mild weight bearing lameness with little if any change in gait
2 : Constant mild weight bearing lameness with little change in gait
3 : Moderate weight bearing lameness with noticeable change in gait
4 : Non weight bearing

*Bone reduction score (Fischer *et al.*, 2004) ;
1 – Anatomic reduction
2 – Good reduction and functional outcome likely
3 – Malaligned and possibly require revision
4 – Unable to achieve adequate reduction

Table 9: Physiological parameters (MEAN ± SE)

PARAMETERS	DAY OF OBSERVATION			
	Pre operative	II week	IV week	VI week
Respiration rate (Per minute)	50.54 ± 2.23	49.90 ± 2.42	49.90 ± 2.56	50.72 ± 1.72
Pulse rate (per minute)	112.90 ± 4.16	112.90 ± 6.02	110.54 ± 2.81	111.90 ± 2.25
Rectal temperature (^{0}C)	39.03 ± 0.14	39.19 ± 0.15	39.00 ± 0.12	39.00 ± 0.13

(n = 12)

Table 10: Haematological and serum biochemical evaluation (MEAN ± SE)

(n = 12)

PARAMETERS		DAYS OF OBSERVATION			
		PREOPERATIVE	II WEEK	IV WEEK	VI WEEK
Hb (g/dl)		13.11 ± 0.66	12.17 ± 0.67**	12.49 ± 0.52	12.07 ± 1.17
VPRC (%)		36.45 ± 0.52	35 ± 0.46**	35.63 ± 0.59	36 ± 0.44
ESR (mm/hr)		4.7 ± 0.19	3.9 ± 0.28**	3.36 ± 0.27*	2.9 ± 0.21
Total Leukocyte Count (per 10^3/cu.mm)		12.43 ± 0.50	11.61 ± 0.47**	11.69 ± 0.42	11.77 ± 0.39
Differential count	N%	69.54 ± 0.65	69.9 ± 0.91	68.72 ± 0.78	68.63 ± 0.76
	L%	28.45 ± 0.70	28.18 ± 1.03	28.90 ± 0.81	29.45 ± 0.63
	M%	2.09 ± 0.28	1.90 ± 0.31	1.81 ± 0.29	2.09 ± 0.28
CRT (seconds)		1.17±0.41	1.00±0.00	1.67±0.52	1.52±0.41
Serum Calcium (mg/dl)		10.65 ± 0.39	9.89 ± 0.37**	9.75 ± 0.27	10.26 ± 0.23**
Serum Phosphorus (mg/dl)		3.7 ± 0.35	3.61 ± 0.33**	3.30 ± 0.25*	3.40 ± 0.27*
Serum ALP (IU/L)		152.3 + 6.78	171.8 + 7.66 **	139.50 + 11.52**	122.8 + 10.48**

* P < 0.05   ** P < 0.01

Plate 2. Radiographic evaluation Case No. 1

a. Preoperative, capital physeal fracture and hip dislocation

b. Postoperative excellent reduction of fracture and dislocation

c. Second week - healing of fracture in dislocated hip

d. Sixth week - Rarefaction of femoral neck

Plate 3. Radiographic evaluation of femoral subtrochanteric fractures

a. Severely distracted overriding subtrochanteric fracture (Case No. 2)

b. The malaligned farcture healed with heavy callus in six weeks (Case No. 2)

c. Minimally displaced subtrochanteric fracture (Case No. 3)

d. Excellent healing of subtrochanteric fracture in four weeks (Case No. 3)

Plate 4. Salter Harris II fracture - Radiographic evaluation

a. Preoperative : (Case No. 7)

b. Second week - progression in healing with little periostial callus (Case No. 7)

c. Sixth week - complete healing (Case No. 7)

d. Complete healing with two cross pins (Case No. 6)

Plate 5. Radiographic evaluation -
Avulsion of tibial tuberosity (Case No. 11)

a. Stress view- stifle showing avulsion of tibial tuberosity and separation of tibial epiphysis

b. Immediate postoperative - tension band wiring

c. Second week - Reduction in fracture gap

d. Complete bridging of fracture gap without periosteal callus in six weeks

Plate 6. Radiographic evaluation - distal humeral fracture (Case No. 12)

a. Preoperative - supracondylar fracture

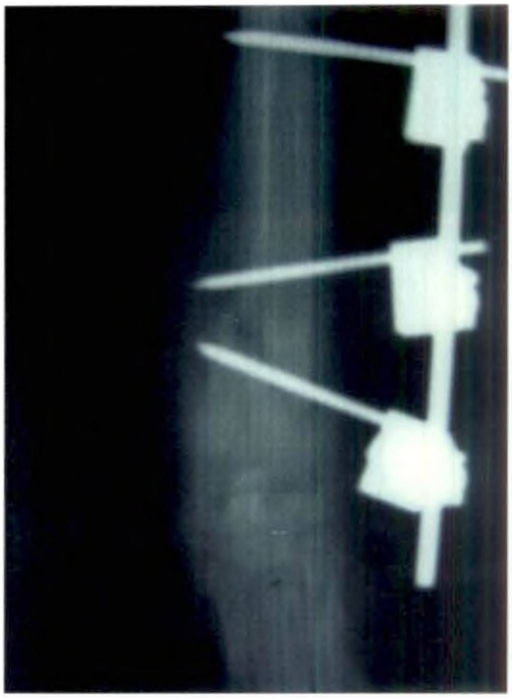
b. Second week - Maintanance of fracture reduction

c. Fourth week - bridging of fracture gap by callus.

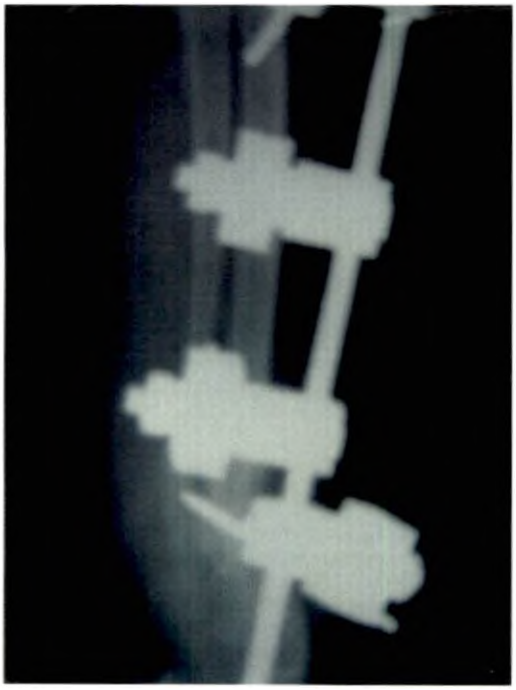
d. Sixth week - bridging of more than 75% fracture gap with moderate callus

Plate 7. Radiographic evaluation of distal radius - ulna fractures

a. Preoperative - Overriding fracture (Case No. 14)



b. Immediate postoperative - Reduction with slight malalignment (Case No. 14)



c. Healing in six weeks (Case No. 14)

d. Immediate postoperative - excellent apposition and alignment of fracture (Case No. 13)

Fig. 17. Second week - a second fracture at femoral neck. Subtrochanteric fracture reduction is maintained (Case No. 5)

Fig. 18. Extensive callus in healing of femoral supracondylar fracture in osteopaenic bone (Case No. 10)

Fig. 19. Radiograph taken one week after excision arthroplasty (Case No. 4)

Fig. 20. Long term follow up- absence of femoral head and pseudoarthrosis (Case No. 1)

Plate 8.Weight bearing in distal femoral fracture

a. Carrying leg- preoperative
(Case No. 7)

b. Second week (Case No. 7)

c. Fourth week (Case No. 7)

c. Sixth week (Case No. 7)

Plate 9. Weight bearing - Avulsion of tibial tuberosity (Case No.11)

a. Preoperative - Favouring the limb at stance

b. Preoperative- abducted limb

c. Third postoperative day

d. Fourth week

Plate 10. Weight bearing - distal radius and ulna fracture (Case No.14.)

a. Preoperative - favouring the limb

b. Second week postoperative

c. Fourth week postoperative

d. Sixth week postoperative

Fig. 21. Recumbant position preoperatively (Case No.9)

Fig. 22. Weight bearing in fourth week postoperative (Case No. 9)

Fig. 23. Radial paralysis in Case No.13 with distal radius and ulna fracture (Preoperative)

Fig. 24. Weight bearing in fourth week postoperative (Case No. 13)

Fig. 25. Preoperative - stance with favouring the limb (Case No. 12)

Fig. 26. Weight bearing in fourth week post operative (Case No. 12)

Fig. 27. Adducted limb with hock turned out in proximal femoral fracture (Case No. 4)

Fig. 28. Non weight bearing on the injured limb fourth week postoperative due to fixation failure (Case No. 4)

Fig. 29. Weight bearing of animal with pseudoarthrosis of hip and rarefaction of femoral head (Case No. 1 on 7th month post operative)

Fig. 30. Quadriceps contracture following distal femoral fracture fixation in six weeks postoperative (Case No. 9)

Fig.31. Valgus deformity of forelimb observed six weeks postoperative following distal radius-ulna fracture (Case No.13)

Discussion

5. DISCUSSION

5.1. INCIDENCE

Fractures of extremities encountered during the study period came to 53 per cent of long bone fractures. Of these, majority were extremity fractures of femur (44.6%), followed by radius and ulna (26.7%), tibia (19.6%) and humerus (8.9%). Similar results were reported by earlier workers (Aithal *et al.*, 1999 and Phillips, 1979).

Of these fracture,only 15 extremity fractures were included in the study and the rest were managed by external coaptation, mainly based on owner convenience and expected level of performance of the pet

Of the fractures studied, 80 per cent of fractures affected hind limb and this could be due to static nature of hind limb compared to forelimb which easily succumbed to accidents (Aithal *et al.*, 1999 and Harasen, 2003a). Higher incidence of hind limb fractures were also reported by Whitney and Schrader (1987).

Articular fractures came to 40 per cent of extremity fractures which did not match with report of Macias and McKee (2003) that articular fractures overrepresented periarticular fractures.

5.1.1. Breed and sex wise

There was no sex predisposition for sustaining extremity fracture according to present study which was also seen in survey of Denny (1978). Increased incidence of male dogs with long bone fractures were reported by earlier workers (Aithal, 1999). No breed predisposition was noticed in the study.

5.1.2. Age wise

Of the extremity fractures studied, 64 per cent occurred in juvenile dogs and 50 per cent affected dogs with open physis. Higher incidence of fracture in young dogs was a notable feature in previous studies (Aithal *et al.*, 1999 and Phillips.1979). Two dogs with open physis had fractures of extremity not involving physis and this could be due to weaker junction of epiphysis and diaphysis (Stoloff, 1983). It can also be connected to the fact that physis fail only before shear and tensional forces (Aithal, 1999 and Marretta and Schrader, 1983).

All proximal femoral fracture occurred in adult dogs as opined by Aithal *et al.* (1999) and Phillips (1979) except for the proximal capital femoral fracture (Gibson *et al.*, 1991). Majority of distal femoral fractures occurred in juvenile dogs which were reported by many workers (Denny and Minter, 1973; Aithal *et al.*, 1999 and Stigen, 1999). All distal metaphyseal and epiphyseal fractures occurred in dogs less than two years age as observed by Alcantra and Stead (1975). Both proximal tibial fractures occurred in young dogs (Denny and Minter, 1973). All the fractures in juvenile dogs were simple fractures which agreed with observation of Macias and McKee (2003) that fractures in immature patients resulted in two fragments. 40 per cent of adult dogs with extremity fracture had multiple fracture of bone which reflected the change in material property of bone with age (Aithal *et al.*, 1999).

5.2. ETIOLOGY

The exciting causes of fractures in the study were road traffic accident and fall from a height which were the major exciting causes of long bone fractures as reported by Aithal *et al.* (1999). All distal femoral fractures in the study occurred due to a fall from a height and this agreed with earlier reports

(Denny and Minter 1973). Two of the five supracondylar fracture of femur occurred in osteopaenic bones and could be considered as pathological fractures, as trauma was minor and within the normal physiological tolerance of femur (Wraighte and Scammell, 2006). Supracondylar fracture due to rickets (Aithal *et al.*, 1999) and metaphyseal osteopathy (Emmerson and Muir, 1997) has been reported earlier.

Both the distal radius and ulna fractures occurred with fall from a height. This may be associated with the front paw striking the ground and getting fixed on falling which concentrate bending stress on distal part of radius and ulna (Aithal *et al.*, 1999). Supracondylar fracture of humerus occurred with automobile accident. Guerin *et al.* (1998) had a similar report regarding etiology and according to Tomlinson (2003), fracture of distal humerus resulted from severe trauma such as automobile accidents. Avulsion of tibial tuberosity with simultaneous separation of proximal epiphysis occurred with minor trauma. This could be explained by the fact that avulsion of tibial tuberosity occurred with intrinsic forces (Skelly *et al.*, 1997) and can occur with pup attempting to surmount an obstacle or run downhill at speed (Dingwall and Sumner-Smith, 1971). Case No. 5 with subtrochanteric fracture had unknown etiology and since animal was confined, it could be suspected to be with minor trauma. Femoral neck fracture with no evidence of trauma had been reported earlier (Phillips, 1974).

5.3. PATTERN OF FRACTURES

All distal femoral fractures were transverse or short oblique in nature which was also observed by Whiteney and Schrader (1987). This was due to fact that all these fracture occurred with fall which created a bending stress on distal femur and ultimately caused oblique fracture (Aithal *et al.*, 1999 and Roush, 2005). Short oblique and transverse fracture of distal radius and ulna and short oblique supracondylar fracture of distal humerus as observed in the study matched with survey done by Aithal *et al.* (1999). Predominance of transverse or comminuted fractures in distal humerus was observed earlier by Whitney and Schrader (1987)

The extremity fractures studied included capital femoral physeal, basicapital, basilar neck, subtrochanteric, supracondylar (Simpson and Lewis, 2003) and Salter Harris II fractures of femur, avulsion of tibial tuberosity with separation of tibial epiphysis and proximal metaphyseal fracture of tibia, supracondylar fracture of humerus (Tomlinson, 2003) and distal radius and ulna fracture.

Physeal fractures encountered were Salter Harris I (proximal femur and proximal tibia), Salter Harris II (distal femur) and Salter Harris V (distal ulna) fractures. Earlier reports on increased incidence of Salter Harris I fracture of proximal femur (Payne, 1993) Salter Harris II fracture of distal femur (Parker and Bloomberg, 1984) and Salter Harris V fracture of distal ulna (Marretta and Schrader, 1983) matched with present study. Presence of hip dislocation and capital physeal fracture as seen in Case No.1 was a rare occurrence and this could be associated with age of animal (Denny, 1971) i.e. with recently closed physis because an open physis is weaker than ligament (Beale, 2004; Cabassu, 2005). In young dogs luxation of femoral head was reported to be associated with avulsion fracture of fovea capitis (Payne, 1993). A similar report on femoral capital physeal fracture with dislocated hip (Lipscomb and Muir, 1998) was not associated with rupture of teres ligament. The femoral capital physeal fracture was typically L shaped (Simpson and Lewis,2003).

Simultaneous subtrochanteric and femoral neck fracture as in Case Nos. 4 and 5 was also reported by Macias and McKee (2003) and Beale (2004). Multiple fractures of proximal femur was also reported by Jeffery (1989) and

Perez-Aparicio and Fjeld (1993). In both the Salter Harris II fractures of distal femur, the caudomedial projection of metaphysis remained with epiphysis and similar observation was reported by and Alcantra and Stead (1975) on majority of Salter Harris II fractures of distal femur. This may be associated with fact that caudal metaphyseal projections are thinner in dogs and seat well into the corresponding depressions on epiphysis. The metaphyseal chip was associated with instability of bone to withstand compression as effectively as cartilage (Culvenor *et al.,* 1978). The typical folded fragment ends in fractures associated with osteopaenic bone, as reported by Morgan (1972), was observed in Case No.9. In avulsion of tibial tuberosity with fracture and separation of epiphysis, the epiphysis was caudally displaced and this could be due to pull of hock extensors on the plateau as described by Clements *et al.* (2003).

In all displaced distal femoral fractures, the proximal fragment was displaced cranially and distal fragment flexed caudally which was the same observation noticed by Wolf (1954) and was due to pull of quadriceps muscle group on proximal and gastrocnemius muscle on distal fragment.

5.4. PRE OPERATIVE PREPARATION

Preoperative preparation of the patient and aseptic techniques followed during the surgery was found satisfactory

5.5. EVALUATION OF TECHNIQUES

5.5.1. Implant selection

Smooth pins were selected because of low cost and easy availability (Sissener *et al.*, 2005). End threaded pins were reported to have no holding advantages over smooth pins and often broke at thread shaft junction (Roush and McLaughlin, 1998) and were costly. As intramedullary pin, the selected pins were *satisfactory and no evidence of pin migration affecting fracture* stability was noticed, which questioned opinion of Church and Schrader (1990). As transfixation pins of external fixator, the selected Steinman pins were satisfactory, but transfixation pins created moderate osteolysis of pin tracts and were found loosened at six weeks but did not affect fracture healing. The only question arose was with bone purchase of smooth K wires when used as cross pins, as pin migration was noticed in Case Nos. 1 and 4.

As cerclage wire, 20G orthopedic wire could not be evaluated even if early implant failure occurred with breakage of wire in Case No.2. Faulty intramedullary pinning in this case might have caused movement at fracture site, and hence wire breakage couldn't be considered as a complication of material property of wire. 20G wire was found satisfactory for tension band wiring in Case No.12, though 18G wire was the standard recommendation in large breeds (Piermattei and Flo, 1997). Larger wire as tension band wire added stability and fastened healing but difficulty to contour it over bone resulted in early failure as reported by Neat *et al.* (2006).

5.5.2. Surgical approach

Craniolateral approach was satisfactory in reduction and fixation of subtrochanteric fractures, though severely displaced subtrochanteric fractures necessitated additional muscle dissection before reduction of fracture. However, the approach was found inadequate to expose femoral head and neck as reported earlier (Ewoldt *et al.*, 2003; Piermati and Greely, 1966; Guerrero *et al.*, 2005). A variation to the approach with incision in craniolateral to caudodistal direction was reported as satisfactory for placement of K wires in capital physeal fractures (Fischer *et al.*, 2004) and ventromedial approach was advocated by Guerrero *et al.* (2005).

Lateral parapatellar approach was excellent in managing supracondylar and physeal fractures of distal femur. The approach was found safe and easy as reported by Aithal *et al.* (1998) and Stigen (1999) and gave adequate exposure of fracture (Piermattei and Greely, 1966).

Lateral approach to proximal tibia to reduce tibial tuberosity avulsion was satisfactory and avoided stifle joint entry. But the incision was extended craniodistally for ease of drilling hole for passage of tension band wire, making the approach associated with extensive incision. Lateral approach was used by Pettit and Slatter (1973) for the same.

Lateral approach to distal humerus exposed supracondylar fracture but was associated with increased haemorrhage. The approach in repairing supracondylar fracture was sufficient and safe for pinning since it required limited exposure but when it comes to other fixation methods like plating the approach become unsafe and unsuitable. Lateral approach was reported to be safe and easier than medial approach (Guerin *et al.*, 1998; McCarteney, 2007) and a craniolateral approach was described by Turner and Hohn (1980).

5.5.3. Reduction of fracture

Fracture reduction can be time consuming part of any surgery (Langely-Hobbs, 2005). Reduction was difficult with displaced subtrochanteric fracture which could be related to severity of displacement and intrinsic instability of the fracture with proximal fragment having greater tendency to ante flex relative to distal fragment (Leger *et al.*, 1982; Onkiehong and Leemans, 2007). Reduction was difficult and was not maintained in long oblique subtrochanteric fracture. Long oblique fractures were reputed for difficulty in reduction because fracture line configuration was inappropriate for bending and levering techniques, and additionally, muscle contraction was not opposed by fracture configuration and hence overriding occurred after reduction (Johnson, 2003). Distal femoral fractures were reduced without much difficulty which was against opinion of Simpson and Lewis (2003) and Beale (2004) that distal femoral fractures were difficult to be reduced due to spasm of quadriceps and hamstring muscles. This could be due to satisfactory muscle relaxation provided by anaesthetics and muscle fatigue with preoperative traction (Johnson, 2003 and Rovesti, 2006).

Applying gentle continous traction on patellar ligament with stifle extended, reduced the avulsed tibial tuberosity effectively in Case No.12 (Piermattei and Flo, 1997). According to Boudrieau (2003), the tuberosity could be easily reduced simply by extending the stifle joint to relieve the pull of quadriceps muscle. There was slight overreduction of fracture in supracondylar femoral fracture of Case No.10 and supracondylar humeral fracture. Cranial angulation or over reduction facilitated proper seating of pin but might reduce fracture stability as revealed by good periosteal callus in them. This agreed with opinion of Simpson and Lewis (2003). In distal femoral fractures, over reduction prevented patellar impingement (Piermattei and Flo, 1997).

Reduction was less than adequate with distal radius and ulna fracture of Case No.14. This could have been eliminated with a limited open approach and reduction of fracture as described by Milovancev and Ralphs (2004) and Piermattei and Flo. (1997). Anatomic realignment of distal radius and ulna fracture could not be done effectively with external manipulation because reduction was hindered by tendency of carpal and digital flexor muscles to create a caudolateral displacement of distal fragment as opined by Milovancev and Ralphs (2004).

Thus, reduction of fracture was anatomic or good with all cases except Case Nos.2 and 14 where the fragments were malaligned.

There was no significant influence of latency of fracture and time taken for reduction and this agreed with Rovesti *et al.* (2006).

5.5.4. Assessment of fixation technique

Selection of internal fixation was based on mechanical, biological and clinical parameters associated with each patient as recommended by Rochat and Payne (1993) and Stiffler (2004). Pins were inserted in various fashions according to fracture configuration and surgical findings.

Repeated efforts to pass pin normograde from trochanteric base to fix femoral capital physeal fracture failed with frequent slippage of extremity on insertion of pin, creating large fracture gap. Similar difficulty in passing K wire was reported by Tyagi *et al.* (2002) in repair of olecranon fracture. Normograde insertion of single K wire from fovea capitis towards femoral neck satisfactorily reduced capital physeal fracture, was found simple and needed less time (Kuzma, 1989). The technique of normograde insertion of pin from fovea capitis was reported earlier by Guerrero *et al.* (2005). However this technique could be recommended only when the fracture occurred with simultaneous hip dislocation which otherwise required transection of teres ligament thus creating instability of joint. According to Miller and Anderson (1993), articular fixation of femoral physeal fracture was easier than implant application from trochanteric base but resulted in destabilization of hip and complications associated with vascular disruption. Presence of articular cartilage deficit created by pin and resultant joint abnormalities could not be evaluated since dislocation persisted and resulted in pseudoarthrosis but the pin being countersunk might not create any problem (Guerrero *et al.*, 2005).

Normograde insertion of pin from cranial aspect of trochanteric base towards femoral head (Ewoldt *et al.*, 2003) done in Case No.4, resulted in inadequate depth of penetration in epiphysis and ultimately failed with distal migration of pin. This was because intra operative estimation of location of implant in epiphysis was difficult with the approach chosen that too in absence of imaging techniques as reported by Kuzma *et al.* (1989) and the approach was reported to be associated with incorrect reduction and poor bone purchase of implant by Guerrero *et al.* (2005). This could be overcome with approximate estimation of safe depth of pin penetration by technique developed by Lorinson *et al.* (1998)

Retrograde insertion of Steinman pin was done in all distal femoral fractures except in Salter Harris fractures. Retrograde insertion was found easier and adduction of limb during pin insertion as described by Piermattei and Flo (1997) avoided impingement of sciatic nerve. Retrograde inserted pin had less bone purchase in distal fragment or required over reduction of distal fractures to achieve adequate seating as was also opined by Parker and Bloomberg (1984) and recommended by Culvenor *et al.* (1978) over normograde insertion from distal bone.

Normograde insertion of pin from proximal fragment based on anatomic landmarks (Case Nos. 2 and 3) was technically difficult but avoided an open surgery. The technique was successful with Case No.3 but failed in Case No. 2 probably due to rotation of proximal fragment associated with fracture, which altered anatomic relations of the bony landmarks used for pinning. Normograde pinning was advocated by Beale (2004) as it avoided impingement of sciatic nerve but could not be considered as a fact since in any case included in the study, retrograde pinning did not create nerve injury.

Normograde pinning from distal fragment through a point cranial to cranial cruciate ligament (Case Nos. 6 and 7) took less time, gave maximum purchase of pin in the smaller epiphyseal fragment and avoided inadvertent damage to cruciate ligament as reported by Aithal *et al.* (1998) and Whitney and Schrader (1987). However the technique required greater technical difficulty to bring pin proximally through trochanteric fossa as well as necessitated opening the joint and created articular cartilage deficit as reported by Culvenor *et al.* (1978). The articular cartilage deficit created by pin did not cause any functional problem as observed by Aithal *et al.* (1998) and could be excused since it provided improved stability (Parker and Bloomberg, 1984).

Antirotational K wires were used along with intramedullary pin in majority of cases because intramedullary pin alone could not provide exact reduction as reported by Parker and Bloomberg (1984). Insertion of auxiliary cross pin was performed with little difficulty and time in all cases and resulted in good stability of fracture. Protrusion of wire from far cortex was observed but did not cause any complication as reported by Leighton and Taylor (1983). Antirotational K wires with intramedullary pin were described for supracondylar fracture of humerus (Anderson *et al.*, 1990) and for distal femoral fractures (Piermattei and Flo., 1997). Use of intramedullary pin to attach humeral condyles to metaphysis was described by Tomlinson (2003).

Insertion of cross pins from medial and lateral condyles using K wires, in Salter Harris II fracture of Case No.6, resulted in good reduction but was technically difficult (Denny, 1991) and caused more soft tissue trauma. K wires were advocated for physeal fracture since they have minimum impact on growth (Cabassu, 2005) and technique of pin insertion from condyles was described in earlier reports (Denny, 1991). Intramedullary pin and auxillary K wire maintained the Salter Harris II fracture of Case No.7 in excellent reduction and healing happened with little periosteal callus. Intramedullary pin and antirotational K wire was reported to create excellent stability of distal femoral physeal fracture by early workers (Simpson and Lewis, 2003)

Intramedullary pinning alone was used in Case Nos. 3 and 10 (Denny and Minter, 1973), though single intramedullary pin was reported to be associated with rotational instability (Piermattei and Flo., 1997). This was because, in Case No.3 the simple minimally displaced fracture could be easily fixed with closed pinning and any auxillary fixation necessitated open approach and in Case No.10 the bone was found too fragile to have a second implant.

Standard method of tension band wiring with two K wires was not done in Case No.12 because the fragment was so small that it may fracture with insertion of more than one K wire. Single K wire maintained alignment and provided good anchorage to the tension band wire. Bending of the K wire proximally over the bone prevented slippage of wire (Pettit and Slatter, 1973). Modifications of technique with passing pins crossing each other at far cortex (Alvarenga *et al.* 1982) and using two tension band wires with each wire over each pin(Pettit and Slatter, 1973) was reported earlier.

External fixation using Type IA configuration was satisfactory in maintaining reduction of distal radius and ulna fracture, was the simplest to apply, had fewer complications and biological osteosynthesis could be employed. Intramedullary pinning of radius was not done because of difficulty in access for pin insertion without damaging joint surfaces and external fixation was considered a choice with unimpeded access (with little soft tissue covering) to all sides of limb (Milovancev and Ralphs, 2004). Though fixation of radius was recommended for radius and ulna fractures, fixation of ulna was carried in Case No. 13. This was because extremity of ulna was larger and hence available for insertion of transfixation pins. Stabilisation of ulna was carried out successfully by Muir and Manley (1994) and Langely-Hobbs (2005) in proximal and distal radius and ulna fractures respectively. Insertion of pins from craniomedial aspect of limb avoided penetration of muscle mass as reported by Milovancev and Ralphs (2004).

Though minimum two pins are recommended in each fragment in ESF (Canapp, 2004), single pin was inserted in distal fragment in Case No.14, due to smaller extremity and stability was not questioned. The only problem encountered with insertion of pins was with distal pin insertion into the small extremity fragment, avoiding fracture gap and physis, which was found technically difficult without imaging techniques.

Frequent lavage with gentamicin mixed normal saline solution lessened the soft tissue complications. It is in agreement with report of Rochat and Payne (1993).

Intramedullary pin plus cross pin maintained reduction of all extremity fracture where it was used. This can be attributed to three point fixation (Parker and Bloomberg, 1984) and excellent bending resistance (Beale, 2004; Roush and McLaughlin, 1998) of intramedullary pin and antirotational action of cross pin (Parker and Bloomberg, 1984). Interfragmentary K wire with internal fixation helped to neutralize rotation, shear, tension and possibly tensional forces as described by Beaver *et al.* (2000), whereas according to Guile (2004) K wires did not provide interfragmentary compression. Good stability of the reduced fractures observed in the study supported the former opinion and secondary type of healing observed with fracture supported latter because primary healing occurred with interfragmentary compression (Doyle, 2004). Fractures stabilized by static cross pinning technique sustained greater loads to failure (Simpson and Lewis, 1993; Harasen, 2001). Single K wire passed normograde from fovea capitis maintained reduction till healing and this could be associated with interlocking shape of physis (Gibson *et al.*, 1991; Simpson and Lewis 2003) and the dislocated position of hip.

Tension band wiring of tibial tuberosity was excellent in maintaining reduction of avulsed tibial tuberosity as well as epiphysis, because both the extremities are connected (Macias and McKee, 2003).

Moderately extensive approach and moderate soft tissue trauma was required with pinning techniques but this could be excused with anatomic reduction. Bone trauma was also moderate with internal fixation techniques adopted. According to Au *et al.* (2008), K wires were minimally disruptive to bone and soft tissue. Though soft tissue trauma could be considered greater with tension band wiring this was not in the region of fracture and the fracture was reduced and fixed with minimum approach. Also the bone trauma with external fixator was at a site farther from fracture site. Thus most rigid mechanical fixation with least surgical trauma as recommended by Stiffler (2004) could be achieved with the techniques used in the study.

5.5.5. External coaptation

External coaptation with plaster of Paris (Gypsona) cast was found helpful as it restricted activity of patient after the fixation, but it failed to restrict movement of hip joint effectively as described by Simpson and Lewis (2003). Macias and McKee (2003) opined external coaptation could be used when strength of internal fixation was less than desirable. Denny (1983) recommended body cast for three weeks after surgical fixation of fracture because premature weight bearing can lead to refracture and Langely-Hobbs *et al.* (1996) recommended Gypsona for this as it was comfortable, cheap and comparatively radioluscent.

Coaptation of limb in extended position after tension band wiring as advised by Pettit and Slatter (1973), relaxed muscles and prevented extreme flexion of joint which could cause implant failure.

5.5.6. Post operative care

Post operative analgesia was found satisfactory with Meloxicam @ 0.5 mg/kg body weight as no signs of pain were reported in any case, except in Case No.4 in which this was associated with increased intra operative soft tissue trauma. Postoperative analgesia was advocated by Auer *et al.* (1996) to avoid continous overload of contralateral limb and by Millis (2004) to avoid reflex inhibition and to promote early limb usage. Meloxicam was reported to be effective in management of post operative pain and in improvement of lameness in dogs (Curry *et al.* 2005).

Though antibiotics were not advocated in clean surgeries not exceeding one hour, post operative antibiotic coverage with ceftriaxone was provided to all animals since presence of implants and soft tissue trauma invited infection and hence required good antibiotic coverage (Rochat, 2001). Cephalosporins were advocated to resist orthopaedic infections by Bubenik and Smith (2003) and Roush and McLaughlin (1998).

Gauzes and cotton were packed between skin and connecting bar of external fixator and whole apparatus was wrapped in light bandage which functioned well in minimizing soft tissue injury with movement of pin and protected animal from impaling itself with fixator and the same method was recommended by early workers (Canapp, 2004). Development of scab at pin entry points satisfactorily prevented infections (Carmichael, 1991).

Restricted activity was advised in all animals for three weeks, followed by leash walking for next three weeks as loading the bone, tendon, ligaments and skeletal muscle should be minimized during the period of inflammatory phase of healing to allow formation of repair tissue whereas micromotion was necessary for formation of periosteal callus (Roush and McLaughlin, 1998).

5.5.7. Implant removal

Implants were not removed unless implant related complications were encountered as advocated by Cabassu (2005). Similar opinions were also reported by early workers, Stiffler (2004) and Roush and McLaughlin (1998). Intramedullary pins were removed in two cases after fracture healing due to seroma formation. External fixator was removed under sedation when fracture gap was found completely bridged by callus. Sedation or general anaesthesia was recommended for removal of external fixators (Canapp, 2004).

5.6. PATIENT EVALUATION

5.6.1. Clinical signs

The clinical signs of fracture like pain, crepitus, soft tissue trauma, abnormal posture and limb dysfunction as described by Roush and Mclaughlin (1998) were noticed with varying degrees of severity in the cases studied. Pain was exhibited in all cases whereas crepitus was not much evident in tibial tuberosity avulsion. Previous reported symptoms of tibial tuberosity avulsion (Pettit and Slatter, 2004) also did not include prominent crepitus. Toe touching posture was noticed with femoral head and neck fracture where as carrying leg posture was observed in majority of distal femoral fractures. Animals with femoral capital physeal, head or neck fractures kept the limb adducted and flexed at stifle as reported by Bennett (1975) and Denny (1991) (Fig.27). Animal kept the limb abducted at stifle as reported by Alvarenga *et al.* (1982) in tibial tuberosity avulsion but medial rotation of paw as reported by Pettit and Slatter (1973) was not observed (Plate 9b). All forelimb fractures were presented with carrying limb lameness (Payne, 1993). With supracondylar fracture of humerus and distal radius-ulna fracture, animal carried affected leg with elbow dropped and with paw resting on dorsal surface (radial paralysis) which could be associated with pain and weakening of extensor musculature (Fig.23)..

5.6.2. Physiological parameters

Rectal temperature (°C), pulse rate (per minute), respiration rate (per minute), capillary refill time (CRT) in seconds and color of mucous membrane of all the dogs were within normal range except for pyrexia noted in Case No.4 which could be due to microfilariasis in the animal.

5.6.3. Functional limb usage

Wight bearing score of animals with proximal femoral fracture was 3.8 and with distal femoral fracture was five preoperatively which progressed by six weeks to 8.6 and 9.8 respectively. All animals with forelimb fracture had score of zero preoperatively and progressed continuously to an average score of 9.3 by six weeks (Fig. 25 and 26). Both cases with tibial fractures had full weight bearing in six weeks. Progressive increase in limb function of animals at two weeks interval after fracture treatment was reported by Fischer *et al.* (2004). The functional outcome was excellent with no lameness in undisplaced subtrochanteric fracture, both Salter Harris fractures of distal femur, both tibial fractures, humeral supracondylar fracture, and distal radius and ulna fracture in Case No.14. Excellent outcome, of avulsion of tibial tuberosity with tension band wiring was reported by Denny and Minter (1973) and of distal femoral fracture with pinning techniques was reported by (Ganesh *et al.*, 2004a; Whitney and Schrader, 1987 and Aithal *et al.*, 1998).

Intermittent lameness noticed with Case No.1 was associated with psudoarthrosis of dislocated leg. Malunion in Case No.2 resulted in intermittent lameness, long after healing of fracture, and this may be due to abnormal stress created by malaligned femur on hip joint which might have created some abnormal joint biomechanics. Change in gait in Case No.13 with valgus deformity of forelimb, and in Case No.5 with possible pseudoarthrosis was minimal. However noticeable change in gait was observed in Case No.9 with quadriceps contracture, and in Case No.4 with excision arthroplasty. Excision arthroplasty and fixation of greater trochanter in dogs with simultaneous femoral neck and trochanteric fracture resulted in slight to marked limping as reported by Denny (1971).Thus in all cases except Case Nos. 4 and 10 the functional outcome was good or excellent as opined by Payne (1993).

The poor results in proximal femoral fractures could not be considered as a failure in pinning techniques, because two cases failed with concurrent injuries i.e. dislocation in Case No.1 and sustaining a second fracture at femoral neck after surgical fixation in Case No. 5.

Even before the healing was radiographically evident, many animals started showing normal limb usage. Less than adequate fracture reduction in Case Nos. 2 and 14 showed good functional outcomes and this agreed with Fischer *et al.* (2004). There was no statistical correlation between the radiographic reduction score and the functional outcome. Similar observation was reported by Perez-Aparicio and Fjeld (1993). Functional outcomes were true measures of successful fracture management (Doyle, 2004) and hence it could be concluded that the management technique followed with pin fixation techniques was successful in 73 per cent cases. Of the rest 27 cent cases the change in gait was not associated with fracture fixation in 50 per cent i.e. with sustaining a second fracture in one and with closure of ulnar physis due to initial trauma in the other.

Prognosis of leg function after repair was good to excellent in supracondylar fracture of humerus (Tomlinson, 2003) and for distal Salter

Harris II fracture of femur (Simpson and Lewis, 2003) and this was found agreeable with the present study.

5.6.4. Neurological examination

Evaluation of neurological system was recommended before surgical repair of fracture to determine extend of damage and offer prognostic information to clients (Roush, 2005).

Conscious proprioception and pedal reflex was absent or sluggish in some cases which came to normal within two to three weeks (Fig 23 and 24). Thus deficit could not be due to direct nerve injury but with neuropraxia as reported by Muir and Manley (1994). Neurological deficit was noticed mainly with forelimb fractures in the study and according to Tomlinson (2003), humeral fracture was associated with partial radial nerve damage (neuropraxia) due to trauma and associated inflammation and this resolved quickly once fracture was stabilized.

5.7. RADIOGRAPHIC EVALUATION

Radiographic evaluation of fracture done preoperatively, postoperatively and at two weeks interval was found sufficient in assessing fracture pattern, success of fixation and progress of healing. As opined by Wraighte and Scammell (2006) evaluation of fracture was important for proper planning of treatment.

5.7.1. Pre operative

Orthogonal views of affected bone were found essential to have an idea of fracture configuration, as opined by Roush and McLaughlin (1998). Frog legged ventro-dorsal view of pelvis was found more effective in exposing femoral head and neck fracture as reported by Beale (2004). Lateral view of femur masked undisplaced femoral neck fracture and a similar report was that by Denny (1971). Stress view of stifle with flexed joint as described by Farrow (1982) detected the epiphyseal separation and displacement of tibia in Case No. 11 which could not be appreciated in normal views. Orthogonal views of stifle were found necessary to evaluate distal femoral fracture of Case No.6 and this agreed with Carmichael *et al.* (1989). Stress view of stifle could be recommended to detect avulsion of tibial tuberosity and separation of epiphysis.

5.7.2. Radiographic healing

All fractures in young dogs healed within the observation period of six weeks. Rapid fracture healing in immature patient have been reported earlier (Rochat and Payne, 1993). Adult dogs with fracture showed appropriate progression towards healing with up to 75 per cent gap bridged by callus. Rapid bone healing thus observed with metaphyseal and physeal fracture could be attributed to more points of bone contact in cancellous bone and the fact that they are rich in cells and blood supply (Wraighte and Scammell, 2006). Case No.3 with undisplaced subtrochanteric fracture healed completely in four weeks which could be associated with the advantages of closed reduction with minimal trauma to soft tissue surrounding fracture as described by Joyner *et al.* (2004). Femoral capital physeal fracture healed with no signs of periosteal callus though single wire was the only fixation. This may be because hip was dislocated and hence no shear forces acted on the fracture line and also the interlocking nature of physis added stability (Gibson, 1991).

Subtrochanteric fracture of Case No.2 was found healing in angulation with extensive thin callus which was due to greater instability at the fracture site with faulty pin and broken cerclage wire. Both the Salter Harris II fractures healed in six weeks, with moderate periosteal callus in Case No.6 and negligible periosteal callus in Case No.7. This callus could be due to periosteal stripping of metaphysis in Salter Harris II fracture (Lewis and Bellah, 1987). Rapid healing was noticed with distal radius and ulna fractures of Case Nos. 13 and 14, though earlier reports suggested a delayed healing tendency in this type fractures. This could be associated with young age of animal, minimization of trauma to soft tissue surrounding fracture and good owner compliance (Joyner *et al.,* 2004).

Though fracture gap was radiographically evident, Case No.14 started using limb normally with mild lameness in two weeks and this pointed the confusing nature of clinical healing of fracture as reported by Sumner-Smith (1974). In all other cases fractures healed uneventfully with moderate periosteal callus. Thus, when pin and wires were the only fixation present, interfragmentary strain on fracture ends due to micromotion at the fracture site lead to bone resorption, followed by callus formation and transformation of fibroblast to bone.

5.8. HAEMATOLOGICAL EVALUATION

The blood parameters studied *viz:* Haemoglobin concentration, Volume of packed red cell (VPRC), Erythrocyte sedimentation rate (ESR), Total leukocyte count (TLC), and Differential leukocyte count (DLC) were within the normal range. Hemoglobin concentration, and VPRC showed a significant decrease in the first two weeks and ESR showed a significant decrease through out the observation. These marginal variations in hemogram may be due to the cellular reaction to trauma during the healing process.

5.9. SERUM BIOCHEMICAL EVALUATION

Serum calcium level significantly decreased up to four weeks and then showed a significant increase. Serum phosphorus showed no significant variation through out the observation period. This did not match with observations of Pandey and Udupa (1981) that no change in calcium level was found following fracture of tibia whereas serum phosphorus level was significantly high between five and 23 days after fracture. However the variation in values of serum calcium and phosphorus levels had no correlation with bone healing according to Singh *et al.* (1976).

Serum alkaline phosphatase showed significant increase in first two weeks and then showed progressive significant decrease. The level of the enzyme remained slightly greater than normal through out the observation. Significant rise in serum alkaline phosphatase observed post-surgery was reported by many workers (Singh *et al.*, 1976; Pandey and Udupa, 1981; Zama *et al.*, 1999 and Aithal *et al.*, 1998). This change could be ascribed to fibrous tissue formation that was related to early stages of bone repair (Singh et *al.*, 1976), and an increased osteoblastic activity (Aithal *et al.*, 1998 and Zama *et al.*, 1999).

5.10. COMPLICATIONS AND THEIR MANAGEMENT

Complications are a reality of fracture repair and its impact on patients can be reduced by prompt diagnosis and treatment (Jackson *et al.*, 2004).

5.10.1. Implant related

Migration of K wire was observed only in Case No.4 during the observation period. Migration of K wire was reported by many workers earlier (Ganesh *et al.*, 2004b; Guille *et al.*, 2004) and was associated with concentration of strain over implant bone interface resulting in bone resorption and loosening of implant (Matis, 2007). Restriction of migration of pin to this animal might be due to failure in restricting activity of animal, mutilated external cast, and the older age of animal. Excess post operative activity

(Macias and Mckee, 2003) and motion at fracture site (Roush and Mclaughlin, 1998) were associated with implant loosening. More cancellous bone in young animals embedded the pin strongly and even rotational instability of pin became negligible (Denny, 1991 and Whitney and Schrader, 1987). Migration of implant after healing was rare (Roush and McLaughlin, 1998), but there was severe migration of K wire in Case No.1 six months after fracture fixation and this might be due to resorption of femoral head and neck by this time. Migration of K wire 3 months after surgery was reported by Guille *et al.* (2003).

Breakage of cerclage wire in Case No.2 might be associated with excess motion at fracture site (Roush and McLaughlin, 1998) and associated strain (Carteney, 2007).

Pin loosening was observed with external fixation of radius and ulna fracture. Pin loosening would have been minimized by low speed power pin insertion, predrilling pin holes and using threaded pins as described by Canapp (2004). Incidence of pin loosening with external fixator in previous reports ranged from 16 to 100 per cent (Marcellin-Little, 2003).

5.10.2. Technique related

Malunion of subtrochanteric fracture was related to faulty normograde pinning of femur and this appeared to be a functional malunion since animal was reported to be using the limb normally. According to Jackson (2004) malunion occurred with inappropriate methods of fixation, failed fixation devices and improper implant use

5.10.3. Closure of physis

All cases with fracture of extremity of bones with an open physis, had a closed growth plate at final follow up i.e. after six weeks, but it did not cause any growth deformity except for Salter Harris V fracture of ulna. Closure of physis could be associated with injury secondary to trauma itself (Johnson *et al.,* 1994), the surgical exposure and manipulation or with injury caused by fixation device (Parker and Bloomberg, 1984). Marretta and Schrader (1983) reported that physeal closure occurred in four weeks with all Salter Harris type I and II fractures of proximal femoral physis regardless of fixation and Parker and Bloomberg (1984) reported that premature closure of physis resulted from all naturally occurring distal physeal fracture of femur regardless of intramedullary fixation adopted and Salter Harris V fracture of ulna invariably closed the growth plate as the germinal cells were damaged as reported by Marretta and Schrader (1983) and conical shape of this physis in dogs transfer trauma in any direction to a crushing injury(Johnson *et al.*, 1994 and Voss and Leikovsky, 2007).

Deformity was not observed with closure of physis in animals because all of them got the fracture at a later stage of their juvenile age and as reported by Prieur (1989) severity of premature closure of physis depended on age of patient and the bone affected. Valgus deformity of forelimb (Roush, 2005) with premature closure of ulna was observed with Salter Harris V fracture of ulna. This could not be detected in initial radiographs as reported by Roush (2005), but signs of closure with presence of bony bridges in physis were observed in follow up radiographs as observed by Prieur (1989). Premature closure of physis was the most common cause of deformity as reported by Johnson and Hulse (2002) and Boudrieau (2003). Closure of ulnar physis did not create any deformity with Case No.14 which could be explained with fact that growth deformities most likely occurred with large breed pups with much remaining growth potential (Maretta and Schrader, 1983). The metaphysis and diaphysis of affected ulna was found increased in diameter and this could be explained by periosteal new bone growth in response to pulling action of interosseous ligament and membrane (Morgan, 1972).

Dislocated femoral head could not be corrected permanently though open reduction was done because the joint capsule and teres ligament was torn away and was not available for repair. Teres ligament have a major role in stability of developing hip (Miller and Anderson, 1993). Extracapsular prosthetic suture as done by Lipscomb and Muir (1998) may be considered in those cases. Both intracapsular fracture femoral head and neck resulted in avascualar necrosis of the fragment. (Guerrero *et al.*, 2005)

Excision arthroplasty conducted in Case No. 4 improved the limb usage of animal in two weeks as reported by owner but still had a noticeable change in gait. Good limb usage after excision arthroplasty was reported in cats (Bennett, 1975) and dogs (Denny, 1971) but according to Payne (1993) it caused varying degrees of gait abnormalities and decreased range of motion of hip joint. Excision arthroplasty was conducted as a second procedure by Gibson *et al.* (1991).

Fate of basilar neck fracture in Case No.5 was unknown since the case was unavailable for radiographic follow up.

Quadriceps contracture observed with Case Nos. 9 and 10 could be associated with prolonged recumbancy of Case No.9 and development of heavy callus and presence of external coaptation in both. A similar report on quadriceps contracture due to two weeks latency in fracture fixation in an animal was associated with prolonged limb disuse (Stiffler, 2004). The muscle contracture happened with entrapment of the muscle in developing callus as reported previously by early workers. (Macias and McKee, 2003; Beale, 2004).

Seroma observed in animals could be associated with irritation caused by movement of pin in the soft tissue as animal moved (Beale, 2004).

Complication rates were higher with proximal femoral fracture and could be attributed to intrinsic instability of the region (Lewis and Bellah, 1987).

Hence the techniques adopted could be recommended for simple extremity fractures with advantages of comparatively less trauma to soft tissue and bone. The techniques were easier and required less instrumentation and moreover satisfactory stability could be attained at the minimum cost. Implant removal needed with other fixation techniques which required additional hospital stay could be avoided and minimum post operative care was required.

Summary

6. SUMMARY

The study was conducted to assess the feasibility of various surgical techniques for the management of fracture of extremity of long bones in dogs and to find out the easy, effective and cheaper technique.

The fractures included in the study were capital physeal (1), basicapital(1), subtrochanteric(4), supracondylar(3) and distal Salter Harris II (2) fractures of femur; avulsion of tibial tuberosity with separation of epiphysis (1)and proximal metaphyseal fracture of tibia (1); supracondylar fracture of humerus (1) and distal metaphyseal fractures of radius and ulna (2). All the animals were subjected to detailed clinical, radiological, haematological and serum biochemical evaluation preoperatively and postoperatively at two weeks interval up to sixth week

Majority of fractures studied occurred in young dogs with an open or recently closed physis and 77 per cent of them involved physis. Closure of physis was observed in all cases at final follow up radiographs. This could not be considered as a premature closure in all, because majority of fractures occurred around the expected age of physeal closure. There was no breed or sex predisposition observed. Etiology of all distal femoral and distal radius and ulna fractures were a fall, and majority of them were short oblique fractures. Fracture pattern of proximal femur was varied in each case, according to variation in age and type of trauma. The avulsion of tibial tuberosity resulted from intrinsic forces as the pup was confined at time of sustaining fracture.

Concurrent injuries observed were hip joint luxation with capital femoral physeal fracture (Case No.1), ipsilateral metacarpal fracture with distal

femoral physeal fracture (Case No.7), and mandibular fracture with distal radius and ulna fracture (Case No. 13), all of which except the first one were managed successfully.

Surgical reduction was carried out in open or closed method depending on fracture location and degree of displacement. For all cases preoperative traction was applied to the limb for 20 minutes and it assisted reduction of fracture.

Steinman pins and K wires, being cheaper versatile and easily available, were used in various fashions to manage the extremity fracture. They were used to function as intramedullary pin, cross pin and as transfixation pins of external fixator.

Except for minimally displaced subtrochanteric fracture and distal radius and ulna fracture, all fractures were reduced and fixed by an open approach and joint exposure was required only with the capital physeal and Salter Harris fractures of femur.

Craniolateral approach was found satisfactory in reduction of lower metaphyseal fracture of proximal femur (F2 to F5) but was inadequate in reduction and fixation of femoral capital and neck fractures, since exposure was minimal. Lateral parapatellar approach was found easy and excellent in exposing the supracondylar and distal physeal fractures of femur (F6 to F10). A modified lateral approach to proximal tibia curving medially and cranially below tibial crest, without opening the joint was satisfactory in reducing fracture of tibial tuberosity (T2), but a larger exposure was needed for tension band wiring. Craniolateral approach was used to repair supracondylar fracture of humerus (H).

Intramedullary pin alone or with an antirotational cross pin was used to immobilize fractures of distal femur, proximal tibia and distal humerus and the results were satisfactory. Subtrochanteric fracture in smaller dogs was managed successfully with pins but their success in larger dogs could not be ascertained.

Normograde and retrograde pinning of femur was found to have advantages and disadvantages. Normograde insertion of pin from trochanteric fossa in closed manner was successful in one case (F2), but resulted in faulty pinning in displaced subtrochanteric fracture (F3). Thus, though the technique avoided manipulation of the fracture site it must be restricted to minimally displaced fracture with the proximal fragment in anatomical position as in F2. Normograde insertion of pin from distal fragment (F6 and F7) gave maximum purchase of pin in distal fragment with pin at a safer site but required arthrotomy and greater surgical skill. Retrograde pinning (F8, F9, F10) was technically easy and the risk of sciatic nerve damage could be successfully prevented by adducting the limb during insertion of pin.

Fixation of femoral head and neck fracture with a cross pin inserted normograde from cranial aspect of trochanteric base (F4) was difficult, since inability to assess position of pin in epiphysis resulted in inadequate seating of pin. Insertion of pin from fovea capitis (F1) was easier but had risk of hip joint laxity and required arthrotomy. Insertion of cross pins in all other extremities was easy.

Type IA external skeletal fixation gave good results in distal radius-ulna fractures. Insertion of transfixation pin of external skeletal fixator in distal fragment of radius and ulna fracture was difficult since the pin must avoid physis below and fracture line above.

Tension band wiring, with a single pin for anchoring the wire, was found satisfactory in managing tibial tuberosity avulsion (T2), as the animal had normal weight bearing in a week and the fracture healed with endosteal callus in six weeks.

Thus, intramedullary pin with antirotational K wires maintained distal femoral and distal humeral fracture in reduction till healing. Subtrochanteric fracture in smaller dogs was also satisfactorily managed with pin fixation. Failure in managing the subtrochanteric, and head and neck fracture of femur in larger dogs occurred with migration of the pin in one case (Case No.4) and with sustaining an additional femoral neck fracture in Case No.5. Capital femoral physeal fracture was maintained in reduction till healing with normograde inserted K wire. Type IA external fixator was successful in bringing faster healing in distal radius and ulna fracture and even with single pin in distal fragment, no instability was observed.

Surgical time did not cross one hour in any cases and soft tissue and bone trauma was minimum/moderate.

Healing was completed in six weeks in all fractures in young dogs and all fracture reduced in closed method. All other cases showed satisfactory progression to healing. Fracture healed with little periosteal callus in all cases where the pins were applied correctly. Angulation in distal radius and ulna fracture was found to be alleviated with developed callus.

Implant related complications included cerclage wire breakage in Case No. 2 and migration of K wire in Case No.4. Technique related complications included faulty pinning in Case No. 2.

Failure in fixing basicapital fracture resulted in poor limb use and excision arthroplasty was done to improve the limb usage. Passive range of motion exercises decreased severity of quadriceps contracture in Case 10.

Full weight bearing on the limb was noticed in all cases in two weeks except in Case Nos. 4 and 5. Sound limb use was noted in Case No.14 in two weeks even though fracture gap was clearly evident radiographically and in Case No.2, with proximal femoral fracture healing in craniocaudal angulation.

Functional limb usage was excellent in all cases and exceptions noted were moderate stiffness at hind limb with quadriceps contracture in Case No. 9, formation of pseudoarthrosis of hip and avascular necrosis of femoral head and neck in Case Nos. 1 and 4. A noticeable change in gait was observed with valgus deformity of forelimb in Case No. 13 with closure of distal ulnar physis.

Alkaline phosphatase level showed an increase for two weeks after fracture repair and then showed progressive decline to normal.

Thus, it could be concluded that,

- Pin fixation techniques with intramedullary pin and derotational cross pin proved excellent in managing extremity fractures of distal femur and humerus and proximal tibia. The method was successful with proximal femoral fractures in smaller dogs.

- Adequacy of pin fixation techniques in proximal femoral fracture of larger dogs need to be studied more since the failure observed in the study could be related to faulty pin seating or with additional post operative injuries.

- Type IA external fixation of radius was successful in managing the extremity fracture of distal radius and ulna.

- A modification to traditional tension band wiring of tibial tuberosity used in study i.e. with anchoring the wire to a single K wire and a modified lateral approach proved satisfactory in managing avulsion of tibial tuberosity.

- Correct application of implant was proved to be the key to success in managing difficult fractures.

- Premature closure of distal ulnar physis could be suspected in all distal radius and ulna fractures in young dogs and a radiographic follow up is necessary before coming to prognosis.

- Avascular necrosis of femoral head was observed in two cases of femoral head and neck fractures.

- Deformity resulting from premature physeal closure depended on the bone involved and growth potential of animal at time of injury.

- Intramedullary pins being cheaper, widely available and versatile with its ability to be used in various fashions, proved successful in managing the difficult extremity fracture of long bones, with minimum cost, time and instrumentation.

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MANAGEMENT OF FRACTURE OF EXTREMITIES OF LONG BONES IN DOGS

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ABSTRACT

The feasibility of various management techniques for fracture of extremity of long bones was evaluated in fourteen clinical cases of dogs with fifteen fractures, presented to Surgery units of Veterinary Hospitals, Mannuthy and Kokkalai, College of Veterinary and Animal sciences, Mannuthy during the period from January 2007 to April 2008. All the animals were subjected to detailed clinical, radiological, haematological and serum biochemical evaluation preoperatively and postoperatively at two weeks interval up to sixth week.

The fractures included in study were capital physeal, basicapital, subtrochanteric, supracondylar and distal Salter Harris II fractures of femur; avulsion of tibial tuberosity with separation of epiphysis and proximal metaphyseal fracture of tibia; supracondylar fracture of humerus and distal metaphyseal fractures of radius and ulna.

Reduction was achieved by open and closed approach and fixation was done using intra medullary pins acting as intra medullary pins, cross pins or as transfixation pins of external fixator. Femoral head and neck fracture was fixed by K wire inserted normograde from fovea capitis or from subtrochanteric area. Subtrochanteric fracture of femur, distal femoral fractures and distal humeral fractures were repaired by intramedullary pinning done normograde or retrograde, either alone (in stable fractures) or with auxillary fixations like cross pins. Avulsion of tibial tuberosity was repaired by tension band wiring and proximal metaphyseal tibial fracture was repaired by a derotational K wire inserted in closed method. Distal metaphyseal fracture of radius and ulna was immobilized with type IA external fixator after closed reduction.

Fracture reduction was satisfactory in 93 per cent of cases. All animals except two dogs with multiple fracture of femur, showed full weight bearing on the limb in two weeks. Long term functional outcome was excellent in 78 per cent dogs. Development of pseudoarthrosis was observed in three dogs with femoral head/neck fracture and resulted in change in gait in two cases.

All fractures in young dogs healed in six weeks and among others, those without fixation failure showed appropriate progression towards healing. Avascular necrosis of femoral head with femoral head/ neck fracture and premature closure of physis were the biological complications noticed. Premature closure of physis caused deformity only in one case.

An increase in level of alkaline phosphatase and a decrease in serum calcium level were observed in earlier phases of fracture healing.

Intramedullary pin and cross pin in distal femoral and humeral fractures, tension band wiring in avulsion of tibial tuberosity, and type IA external fixator in distal radius and ulna fracture were found excellent. Success of using pins in proximal femoral fractures in large dogs need further study.