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EVALUATION OF PLATE OSTEOSYNTHESIS FOR THE MANAGEMENT OF LONG BONE FRACTURES IN DOGS

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

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DECLARATION

I hereby declare that the thesis entitled "**EVALUATION OF PLATE OSTEOSYNTHESIS FOR THE MANAGEMENT OF LONG BONE FRACTURES IN DOGS**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"EVALUATION OF PLATE OSTEOSYNTHESIS FOR THE MANAGEMENT OF LONG BONE FRACTURES IN DOGS"** is a record of research work done independently by K. Unnikrishnan, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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K. Unnikrishnan

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Introduction

1. INTRODUCTION

Fracture of long bones in dogs is the most common orthopaedic ailment encountered in small animal veterinary practice. The incidence of fractures has been on the rise for the last decade and the major attributable reasons are increased vehicular traffic and a hike in dog population especially that of stray dogs (Aithal *et al.* 1999). A majority of the long bone fractures involve the diaphysis. The treatment goal of any fracture fixation is to restore the patient to normal function as quickly as possible.

The four principle of fracture fixation developed by the Association for Osteosynthesis (AO) are accurate anatomical reduction, rigid fixation, atraumatic surgical technique and early return to pain free movement and weight bearing to minimize fracture disease (Denny, 1991).

Bone plating is considered as one of the ideal and stable internal fixation technique for fracture immobilization. Properly applied bone plates have the potential to restore the stability of the fractured bone and allow early return of the limb function. In addition, they resist the axial loading, torsional and bending forces that act on fractured bone (Rahal *et al.*, 2008).

Even though external coaptation is suggested as a cheap and effective method of fracture stabilization, it is a less rigid form of fixation suitable only for stable fractures distal to the elbow or stifle joint and the animal may mutilate it. Moreover, external limb splintage often results in loss of limb function due to fracture disease characterized by muscle atrophy, tissue adhesions, joint stiffness and osteoporosis.

The ultimate aim of internal fixation is proper reduction and immobilization of the fracture so that early ambulance is obtained. Although many internal fixation techniques are in vogue, each of them has its own merits and demerits. Intramedullary pinning is the most commonly employed fixation method as it requires less expertise, time, energy and money, but the rigidity is less compared to plating. Fractures immobilized with intramedullary pins are more prone to rotational instability and the migration of pins often results in serious consequences like joint stiffness and spread of infection.

External skeletal fixation methods are gaining popularity as a less invasive technique than bone plating with almost the same rigidity. But the problems with such fixations in veterinary patients are increased postoperative morbidity and restriction of free movement (Gemmil, 2007).

Unlike other methods like intramedullary pinning, the stabilization of fragments are more with bone plating and the devices are not exposed to outside causing discomfort to the patient and subsequent infection. When properly applied, bone plating produces minimum or no callus, provide stable fixation and facilitates early ambulation. Once the healing is complete, the device may or may not be removed.

Extensive surgical intervention needed, higher cost of implants and high technical precision and expertise required in the application of plates and screws are to be considered while adopting bone plating as an immobilization method for fractures.

Plates may be inserted to function as a compression plate, a neutralization plate or as a buttress plate. Such names do not imply anything about the physical characteristics of the plate, but only its function. The selection of plating technique depends upon the type of patient, type of fracture and the type of bone involved. The success of plating is also depended upon the type of fracture, fragments, patient's tolerance, availability of materials and the postoperative management given to the patient.

Adoption of biological osteosynthesis principles has been associated with several alterations in traditional plating techniques among which are the use of longer plates, decrease in the number of plate screws and more importantly of interfragmentary reduction screws. This type of fracture stabilization also favours the preservation of a biological environment indispensable to bone healing without disrupting the fracture haematoma. This led to the evolution of new generation plates like the limited contact dynamic compression plate and the locking compression plates. However the superiority of these plates over the traditional dynamic compression plates (DCP) has not been proven beyond doubt (Uhthoff *et al.*, 2006). Moreover traditional plating has its own advantages in veterinary patients like minimum post operative care required and high comfort level provided to the animal.

The importance of radiography in the diagnosis and treatment of orthopaedic problems and evaluation of fracture reduction techniques need not be overemphasized. Combined with clinical evaluation it still forms a cheap and invaluable tool to critically evaluate the accuracy of fracture reduction, implant usage, healing and soft tissue changes associated with fracture fixation like muscle atrophy.

Scanning of the available veterinary literature revealed that comprehensive study reports on plate osteosynthesis are scanty from India.

Hence the present study was undertaken with the objective of evaluating the effectiveness of bone plating for the treatment of fracture of long bones in dogs and the radiographic evaluation of healing process.

Review of Literature

2. REVIEW OF LITERATURE

2.1 INCIDENCE OF FRACTURE

2.1.1 Age and sex wise distribution

The pattern of trauma in 1000 urban dogs and cats were recorded by Kolata *et al.* (1974), among which 871 were dogs. Of the total injured dogs, 565 (65.4%) were males and 299 (33.7%) were females. The median age of incidence of trauma was 1.9 years.

Phillips (1979) had undertaken a survey of fractures in dogs and cats and found that males were more commonly involved than females. Approximately 80% of fracture occurred in animals less than three years of age.

Wong (1984) conducted a survey of fractures in the dog and cat. Among 61 canine fractures recorded, 80% occurred in animals less than two years. Males were more frequently involved than females.

From a survey, Boone *et al.* (1986) found that greater than 50% of fractures occurred in juveniles less than one year.

Thilagar and Balasubramanian (1988) conducted a retrospective study in the incidence and anatomical location of fractures in dogs and found a higher incidence in males (67.1%) than females (32.9%). Fractures were more common in pups between three to six months age (26.6%) and day old to three months (20%).

Balagopalan *et al.* (1995) reviewed 208 cases of fractures in dogs and observed a higher incidence in the age group of three to six months (30.8%) followed by day old to three months (27.9%). In all the age groups except two to three and four to five years, males were more involved than females and the incidence of fracture was highest in the age group of zero to three months (72.4%).

In a survey conducted on fractures that had occurred between 1976 and 1995, Aithal *et al.* (1999) recorded 402 cases. Male dogs (63.16%) were significantly more involved than females (36.84%). Young dogs aged less than one year were more frequently affected (56.65%) than adults.

On reviewing 30 clinical cases of fractures treated during the period from 1988 to 1994, Singh *et al.* (1999) found that majority of fractures occurred in the age group of six to eight years. The number of males affected was more than the females.

In a retrospective study on bone fractures among dogs, Rani *et al.* (2004) found that fractures were more common in younger animals aged less than one year (58.82%) and the incidence was higher in the age group of seven to nine months.

2.1.2 Breed wise distribution

Thilagar and Balasubramanian (1988) found that the highest incidence of fracture was among Non-descript breeds (51.9%) followed by Pomeranian (29.2%) and Alsatian (13%).

Balagopalan *et al.* (1995) observed a high incidence of fracture among Alsatian breed (27.9%) followed by Dobermann Pinscher (17.8%), Non-descript (17.3%) and Pomeranian (15.4%).

In a survey of 402 cases of dog fractures, Aithal *et al.* (1999) observed that Non-descript/indigenous breeds of dogs were most commonly affected. This was attributed to high population of indigenous breeds in the locality. These local dogs were usually let loose to roam outside freely and thus more susceptible to road accidents.

A retrospective study by Rani *et al.* (2004) revealed a high incidence of fracture among Non-descript dogs (54.12%) followed by Pomeranian (12.94%) and other breeds. They also attributed this to higher population of Non-descript dogs in the area under study.

2.1.3 Fracture etiology

According to Kolata *et al.* (1974), motor vehicle hit caused the maximum number of trauma cases (52.9%) followed by injuries due to sharp objects (11.0%) and that due to animal interactions (10.2%). Fall from a height contributed 6.2% of cases. Male dogs were injured significantly more frequently as a result of animal interactions and female dogs injured mainly from falls from heights, crushing or burns.

Road traffic accidents, fall from heights, crush injuries, and animal interactions were the major causes of fracture as observed by Phillips (1979). They constituted 76.9%, 12.8%, 6% and 2.3% of total etiological factors respectively.

Wong (1984) observed that road traffic accidents were the principal cause of fracture in dogs. Trauma as a result of being kicked or hit with an object contributed substantially as a cause.

The major causes of fracture as observed by Marcellin-Little (1998) were motor vehicle accidents, gun shots, or minor traumas.

Automobile accidents (46.86%) and fall / jump from height (39.11%) were the major exciting causes of fracture as observed by Aithal *et al.* (1999).

According to Beale (2004), fractures of femur occurred after substantial trauma such as vehicle accidents and most femur fractures were closed because of the heavy overlying muscles.

2.1.4 *Anatomical location and type of fractures*

Phillips (1979) found that bones most commonly fractured in dogs were radius and ulna (17.3%) followed by pelvis (15.8%), femur (14.8%) and tibia (14.8%) in that order.

From a survey, Boone *et al.* (1986) found that tibial fractures accounted for 19.6% of the total fracture cases and diaphyseal fractures of tibia occupied 80.85% of total tibial fracture case load.

Thilagar and Balasubramanian (1988) observed a prevalence of radius and ulna fractures (31.4%) in a retrospective study. This was followed by fracture of tibia and fibula (30.4%) and femur (14.7%). The lowest were fractures of humerus. Pelvic limb fractures (27.5%) were more compared to that of pectoral limb (14.2%). This was attributed to the trauma that caused fractures. Incidence was highest involving the midshaft of radius and ulna (63.3%) followed by fracture of lower third of diaphysis (31.4%). In the tibia and fibula, lower third diaphyseal fractures (52.4%) were more common than fracture of middle third (34.9%).

Balagopalan *et al.* (1995) found oblique fractures (32.6%) to be predominant among long bone fractures followed by transverse (23.2%) and epiphyseal separation (11.6%). Comminuted fractures were more observed in femur and tibia (7.4% and 15.4% respectively). Fractures of femur were the highest (38.9%) followed by that of tibia (18.8%). The lowest incidence was observed in the scapula. Fractures of hind limb (65.9%) were more than that of fore limb (21.2%).

According to Marcellin-Little (1998), humeral fractures were common in dogs and represented 10% of all limb fractures. Three classic patterns existed: approximately 20% of humeral fractures were physeal fractures in immature animals; about 50% were diaphyseal fractures resulting from a major trauma and approximately 20% were condylar fractures.

Singh *et al.* (1999) found that regardless of breed, most of the fractures involved shaft of bones and were transverse (40%), over riding (30%), oblique (23.3%) and distracted (1%) in nature. Fractures were more in the hind limb (60%) as compared to fore limb (40%). Incidence was common in femur (36.6%) followed by tibia (23.3%).

Harasen (2003) observed that 28% of long bone fractures occurred in the femoral diaphysis of which 60% were simple transverse, oblique or had only one reducible wedge fragment. Among the other long bones, 16% of fractures occurred in the tibial diaphysis and of these, 62% were simple transverse or oblique while 38% were comminuted. According to him, 14% of long bone fractures in dogs involved the distal one third which was the most common site of radial fracture and accounted for 85% of total radial fractures.

2.2. FRACTURE BIOMECHANICS

2.2.1 Fracture forces

According to Smith (1985), while performing its function, bone had to experience two types of imposed forces namely intrinsic and extrinsic forces. High energy trauma such as automobile accidents had no limitations as magnitude or direction of application. Five basic fracture forces were bending, compression, shear, tension and torsion.

Compressive forces occurred from axial loading of the bone and were directly related to the weight of the patient and usage of leg while tension forces were also axial forces that pulled the fracture apart. Bending forces caused compression of one side and tension on the other. Torsional forces occurred from rotation of the bone. Shearing forces were secondary to axial compressive forces acting on an oblique fracture and acted parallel to the fracture line (Stiffler, 2004).

2.2.2. Fracture pattern and biomechanics

Arnoczky and Wilson (1990) observed that bone specimens exhibited specific failure or fracture patterns associated with different modes of loading. When loaded in tension a bone would fail with a fracture plane oriented approximately perpendicular to the applied force. If loaded in compression, the fracture plane would generally be an oblique angle to the applied force.

According to Hulse and Hyman (2003), torsion caused internal shear stress perpendicular to the long axis of bone. The result was rotational deformation and lateral displacement of the fracture. Torsion also caused internal tensile and compressive stress oblique to the long axis of the bone. Long bones were subjected to eccentric loading and could be compared to a bent column.

According to Radasch (1999), shear loading occurred when a force was applied parallel to the bone's surface causing it to slide past another surface and resulting in angular deformation. Bone was weakest when subjected to shear stress. Bending occurred when a load was applied to a bone causing it to bend about its longitudinal axis. Such forces could result as a result of extrinsic forces such as automobile trauma or blunt trauma that were applied perpendicular to the diaphysis.

For long bone fractures, resistance to bending and torsion was of primary importance. With comminuted fractures, the axial collapse of fragments must also be resisted (Gemmil, 2007).

Lipowitz (n.d) observed that fractures produced by pure bending forces tend to be transverse or short oblique. Fracture resulting from torsional loads was spiral in form. The spiral was created by the combined effects of both shear and tensile stresses.

2.2.3 Biomechanics of plates and screws

Nunamaker (1985) observed that plates used for internal fixation were strongest in tension or compression and weakest in bending. Plate fixations were also weak in torsion; however this weakness was not related to the plate itself but to its fasteners, the screws. When using a compression plate, the objective was to place the plate on the tension side of the bone.

Lipowitz (n.d) observed that the bending stiffness of a plated bone was related to the length of the plate; the longer the plate the greater the stiffness. Open screw holes especially those located at or near a fracture line acted as a stress riser, predisposing the plate to fatigue failure. If fracture gap existed especially on the compression side of long bone, the plate was susceptible to bending stresses that could result in fatigue failure.

2.3 BONE HEALING

According to Braden and Brinker (1976), fractured limb could proceed to clinical and bony union in several different ways. The mode of osteogenesis was due to the stability of fixation device and callus production was directly proportional to stability.

Newton (1985) found that primary fracture healing occurred when rigid fixation of fracture was accomplished. In such cases there was no motion at the fracture sites.

Remedios (1999) opined that secondary healing could be divided in to three sequential phases, inflammation repair and remodeling. The inflammatory response was initiated by damaged soft tissue, periosteum and medullary contents.

Perren (2002) observed that indirect healing consisted of the sequential steps of tissue differentiation, resorption of the surfaces of fracture and uniting of the fracture fragment by callus. Finally the fracture underwent a long lasting internal remodeling. Direct healing followed stable fixation and compression and the bone healing occurred without apparent callus

According to Hulse and Hyman (2003), the stability provided by the implant coupled with the biological environment of the fracture surface was the determining factor in deciding the type of healing.

Roush (2005) reported that the type of bone healing was observed to be dependent in the strain across the fracture gap. Primary healing occurred when there was direct bridging of the fracture gap by Haversian bone. This occurred only under small fracture gaps and under extreme rigidity.

2.4 CLASSIFICATION AND DESCRIPTION OF FRACTURES

According to Lipowitz (n.d), fractures were classified and described based on the severity of the fracture, whether it had communicated with the outside through the skin, the shape of fracture line and the anatomical location of the fracture within an individual bone. A transverse fracture was with a fracture line transverse (perpendicular) to the long axis of the bone. An oblique fracture had a fracture line that was at an angle to the long axis of the bone with the two cortices of the bone involved being on the same plane without spiralling.

2.5 FRACTURES OF LONG BONES

2.5.1 Anatomical considerations

2.5.1.1 Humerus

According to Turner (2005), the greatest anatomical concern was for the radial nerve which innervated muscles controlling elbow and carpal extension. The nerve coursed from the proximo-medial surface of the shoulder in the axilla along the caudal aspect of humerus to lie over lateral aspect of diaphysis just over the brachialis muscle. Medially, the median nerve passed over the cranio- medial surface while the ulnar nerve coursed along the caudo-medial aspect of humerus. These neurological structures must all be identified and protected, not only during the surgical approach but also during fracture reduction and implantation of fixation device.

2.5.1.2 Radius and ulna

According to Milovancev and Ralphs (2004), radius was the main weight bearing bone of the pair. Its proximal articulation at the elbow was with the humerus via the articular fovea and the ulna via the ulnar notch. The distal articulation at the carpal was primarily with the radial carpal bone, the ulnar carpal bone to a lesser extent and the ulna laterally. The radial styloid process functioned as an attachment for the distal radial collateral ligament which provided medial carpal stability. The distal two thirds of ante- bracheum were not covered by any significant musculature. The major blood supply to the radius and ulna was provided by the diaphyseal arteries entering via nutrient foramen. They arised as branches of the palmar interosseous artery.

2.5.1.3 Femur

The femoral diaphysis did not have muscle insertions on its cranial, medial and lateral surfaces, but had a loose association with overlying muscles of the quadriceps group. The location of sciatic nerve caudal to the femoral diaphysis and deep to the biceps femoris muscle was to be considered during retraction and fracture reduction to avoid iatrogenic injury (Simpson and Lewis, 2003).

2.5.1.4 Tibia and fibula

Johnson and Boone (1993) described the surgical anatomy of tibia. Tibia articulated proximally with the femur, distally with the tarsus, and on its lateral side both proximally and distally with the fibula. The cranial process was the tibial tuberosity which provided insertion for the patellar ligament. The tibial tuberosity continued distally as the cranial border of the tibia, before tapering in to the diaphysis. The shaft was slightly 'S' shaped when viewed cranially and laterally. The main afferent artery was the caudal tibial artery which entered the medullary canal through the nutrient foramen in the caudo lateral edge at the junction of the proximal and middle thirds.

2.6 PREOPERATIVE CONSIDERATIONS

Spackman *et al.* (1984) found that the overall prevalence of thoracic wall and pulmonary trauma in dogs sustaining fractures as a result of automobile accidents was 38.9%. Pulmonary contusion, pneumo-thorax and fractured ribs were the most common injuries.

According to Roush (2005), approximately 60% of animals with limb fractures had radiographic, electrocardiographic or other evidence of thoracic trauma; whereas only 20% of affected animals had associated clinical signs. The most important action in fracture diagnosis and management was to thoroughly assess the traumatized animal for other injuries of core body systems particularly occult injuries of the thorax and abdomen.

2.6.1 Evaluation of the patient

2.6.1.1 Physical examination

The most consistently noted clinical sign in fracture was loss of function of the affected region as opined by Wong, (1984). Crepitus could be evinced only in 20% cases.

Animals with fracture were often presented with limb dysfunction, pain, fracture instability, overlying soft tissue trauma, abnormal posture or limb position or crepitus (Roush and McLaughlin, 1998).

Rochat (2001b) opined that the first step in the management of a patient with fracture was to assess its overall health. Factors like age, temperament, body weight, general health and weight bearing ability of other limbs played a major role in the treatment outcome.

Piermattei *et al.* (2006) described the symptoms of long bone fracture as pain or localized tenderness, deformity or change in angulation, abnormal mobility, local swelling, loss of function and crepitus.

2.6.1.2 Orthopaedic examination

According to Whittick and Simpson (1990), the first phase of orthopaedic examination commenced with observation of the animal during ambulation, or gaiting, then at rest in a stance. The three kinetic requirements of ambulation were locomotion, adaptation and equilibrium.

2.6.1.2.1 Functional limb usage evaluation

Sumner-Smith (1993) observed that it was necessary to have a consistent grading method for lameness to enable clinicians to interpret previously recorded notes and allow colleagues to appreciate whether or not an animal was lamer or less lame than at the previous examination. A 0 to10 grading system was quite useful to quantify lameness.

2.6.1.2.2 Neurological examination

Blythe (1998) observed that neurologic dysfunction could be differentiated by assessment of presence or absence of reflexes and conducting tests for conscious proprioception.

Assessment of neurological status was essential to rule out central nervous system injuries and peripheral, fracture associated injuries (Roush and McLaughlin, 1998).

According to Johnson and Hulse (2002a), every orthopaedic examination should include a neurologic examination since most of the neurological disorders might mimic or occur concurrently to orthopaedic ailments.

2.6.2 Preoperative radiographic assessment

Radiograph was essential for identifying and defining a fracture. When assessing a fracture radiographically, at least two views should be made. Radiograph should include entire bone and adjacent joints. Fracture should be classified according to its radiographic appearance as to type, location and position of fracture fragments (Biery, 1985).

According to Sande (1999), a general description of the fracture should give the name of the bone and the location of the fracture within the bone. Long bones might be divided in to proximal, middle and distal thirds. The severity was described by the terms simple, comminuted, multiple or segmental. The direction of the fracture line or lines completed the verbal picture of findings. The anatomy of the fracture was described by the position of the distal fracture fragment or limb segment in relation to the proximal segment.

2.6.3 Haematological parameters

A complete haematological evaluation was an essential part of preoperative examination of the orthopaedic patient to assess the health status and to determine the fitness for anaesthesia and surgery. Any deficit had to be corrected in the preoperative period itself (Knowles, 1990).

2.6.4 Serum biochemical evaluation

Singh *et al.* (1976) found no correlation between bone healing and serum calcium and phosphorus levels, but a significant rise in serum concentration of alkaline phosphatase (ALP) was seen at seven and fourteen days post surgically. Increased serum ALP was ascribed to fibrous tissue formation that was related to the early stages of bone repair.

Julie (2005) observed that serum alkaline phosphatase level showed a significant increase during the first two weeks after fixation of fracture and then showed a significant decrease by the fourth week. Significant decrease in serum calcium concentration was also recorded.

On conducting a comparative evaluation of biochemical parameters during fracture healing in dogs, Hegade *et al.* (2007) observed that serum ALP level was significantly higher on the operative day than rest of the postoperative days. Serum calcium and phosphorus levels fluctuated within normal limits.

Komnenou *et al.* (2008) studied serum ALP activity in dogs with closed long bone diaphyseal fracture treated surgically from the preoperative day until bone union was completed or signs of nonunion were evident. The ALP activity increased depending on size of the callus with maximum level reaching on day 10. The level returned to normal within two months in cases of healed fractures and remained elevated up to three to five months in cases of delayed unions and then returned to normal after healing.

Remya (2008) observed a significant increase in serum alkaline phosphatase level during the first two weeks after fixation of fracture and then a significant progressive decrease by the fourth week. Significant decrease in serum calcium concentration was also recorded. Serum calcium levels significantly reduced for the first four weeks and thereafter showed a significant increase. But serum phosphorus level showed no significant variation.

2.6.5 Preoperative stabilization of the patient

Johnson (1999) opined that open wounds presented with fracture might be initially managed by clipping the adjacent hair; thoroughly cleaning the wound and applying a bandage to both protect the wound from further bacterial contamination and also to aid in debridement of necrotic soft tissue.

According to Brady and King (2000), correction of hypovolaemia was the key to restoring perfusion, correcting tissue oxygen debt and minimizing end-organ insult.

Rochat (2001b) advised temporary immobilization of the fractured limb to reduce patient discomfort.

Soontornvipart *et al.* (2003) described Cephalosporins as the most commonly used antibiotic for surgical prophylaxis. The advantages were low toxicity, comparatively cheaper and bactericidal spectrum of activity.

Deneuche *et al.* (2004) found that pre-operative administration of meloxicam at the rate 0.2 mg/kg body weight was a safe and effective method of controlling postoperative pain for up to 24 hours in dogs undergoing orthopaedic surgery.

A Robert Johns bandage was recommended as soon as possible after diagnosis of a tibial fracture to immobilize the fracture and protect the surrounding soft tissue structures from damage (Seaman and Simpson, 2004).

According to Houlton and Dunning (2005), perioperative antibiotic prophylaxis was not recommended in clean orthopaedic procedures except when the procedure time exceeded 90 minutes, metallic implants were used or extreme soft tissue injury was present.

2.7 DECISION MAKING AND IMPLANT SELECTION

2.7.1 Fracture assessment score

Aron (1998) opined that based on the patient fracture assessment scale from 1 to 10, the surgeon could be guided into the most correct fracture management regime. The patient was assessed using the treatment scale. The lower the preoperative score, the more difficult was the treatment.

Johnson and Hulse (2002a) opined that each fracture fixation represented a timing race between implant failure and fracture. Implant selection based solely in fracture configuration could lead to significant complications and failures as it ignored important mechanical, biological and clinical parameters that affected patient outcome. Consideration of these factors allowed a fracture assessment score to be developed to assist in implant selection. The score ranged from 1 to 10. The lower end of the scale represented mechanical, biologic and clinical factors that did not favour rapid bone union and return to function; whereas upper end of scale represented those factors that favoured rapid bone union and return to function.

Piermattei *et al.* (2006) correlated fracture patient scoring system with fixation methods as follows; score of 9 or 10: transverse or short oblique fractures- compression plate; score of 8 (7) to 9: long oblique or spiral fractures with a reducible wedge- neutralization plate; score of 4 (3) to 7: wedge fracture- neutralization plate; Score of 1 to 3: complex fracture- buttress plate

2.7.2 Preoperative fracture plan

Egger and Whittik (1990) found that bone plates and screws were to be selected based on body weight of the patient. Other factors to be considered were cortex quality, location and type of fracture, age and breed of the patient.

Jones (1994) opined that before embarking on the definitive treatment for fracture, the case should be evaluated to determine the means of fixation that would best achieve the AO/ASIF aims for particular fracture. Appropriate size of implants could be determined by consulting published tables based on specific bone and weight of the patient as well as from measurements prepared from radiographs. This was referred to as the stage of fracture plan.

Houlton and Dunning (2005) opined that patient's intact contralateral bone could be used as a template to reconstruct the fractured bone.

While observing the basic fundamentals of implant selection, Piermattei *et al.* (2006) found that the most consistent factor in choosing the size of the implant was the weight of the patient. To provide guideline in selecting proper bone plate and screw size, veterinary implant chart was prepared by the AO vet group.

2.7.2.1 Screws

Schatzker (1991) reported that screws were used either to fasten plates or similar devices onto bone or as lag screws to hold together fragments of bone. They could be differentiated by the manner in which they were inserted in to the bone, their function, their size and the typed of bone they were intended for. Thus they were differentiated into self-tapping and non self tapping screws, lag screws, and large and small fragment cortical and cancellous screws.

According to Conzemius and Swainson (1999), use of screw sizes greater than 25% to 30% of the diameter of the bone had to be avoided to prevent reduction in bone strength and stress concentration at the screw hole.

Cortical screws had less depth between threads and more threads per screw (low pitch) allowing for increased engagement with dense cortical bone. Cancellous screws had increased depth between fewer threads (high pitch) to allow for an increased hold in metaphyseal trabecular bone. Additional screw types included self tapping screws, cannulated screws and partially threaded screws (Stiffler, 2004).

2.7.2.2 Plates

DeYoung and Probst (1992) opined that a plate could serve various functions depending on the manner in which it was used. It could act as a compression or tension band plate if placed on the tension side of a weight bearing bone or could act as a neutralization plate if it was used to protect a comminuted area that had been reconstructed with lag screws. The plate might also function as a buttress plate if it was used to bridge a diaphyseal defect.

2.7.2.2.1 Dynamic compression plate (DCP)

Denny (1991) observed that the screw hole of DCP was based on the spherical gliding principle. This enabled the plate to be used as a self compressing plate. Insertion of a screw in the load position would displace the bone beneath the plate towards the fracture site as the screw was tightened against the semi cylindrical slope of the screw hole. Once the screws were tightened, the plate was placed under tension and the fracture site was compressed.

2.7.2.2.2 Reconstruction plates

According to Koch (2005), reconstruction plates were characterized by deep notches between holes which permitted contouring in an additional plane that was not possible with regular plates. They were not as strong as compression plates and might be further weakened by heavy contouring. Special bending pliers were required for contouring. The holes were oval to allow for dynamic compression. These plates were especially useful to repair fractures of bones with complex 3-D geometry. They were available in the dimensions of 2.7mm, 3.5mm and 4.5mm.

Conzemius and Swainson (1999) observed that reconstruction plates worked well in areas where plate contouring could be difficult and the oval screw holes increased the versatility of the angle at which screws could be placed, however they were less resistant to bending forces

Reconstruction plates were considerably weaker than the equivalent sized DCP. Their primary advantage was that they could be confirmed to irregularly shaped and curved bones such as pelvis, mandible and maxilla (Roe, 2003).

2.8 EVALUATION OF THE TECHNIQUE

2.8.1 Anaesthesia

Raghavan *et al.* (1979) observed that xylazine could be used as a pre-anaesthetic agent in dogs at the dose rate of 1mg/Kg body weight which reduced the quantity of anesthetic and facilitated easy handling.

Klide (1985) opined that when combined with ketamine, diazepam usually spared the cardiovascular system. When healthy dogs were administered with diazepam in varying doses of 0.5mg, 1mg, and 2.5mg/kg body weight intravenously, no change in heart rate or blood pressure was observed.

Moens and Fargetton (1990) found that 1mg/Kg body weight xylazine and 15mg/Kg body weight of ketamine rapidly induced an anaesthetic state that permitted endotracheal intubation with the absence of the pedal reflex and with good muscle relaxation.

While anaesthetizing a dog for compression plate fixation, Ayyappan *et al.* (1999) premedicated it with atropine sulphate at the rate of 0.04 mg/Kg body weight i.m. and xylazine at the rate of 1 mg/ Kg body weight.

Adetunji *et al.* (2002) observed that administration of propofol by either repeat bolus injection or constant rate infusion provided rapid induction of anaesthesia without serious side effects in dogs premedicated with xylazine.

Julie (2005) obtained satisfactory plane of anaesthesia for orthopedic surgery by premedicating dogs with atropine followed by xylazine at the rate of one mg/kg body weight. Anaesthesia was induced with intramuscular administration of ketamine hydrochloride at the rate of 5mg/kg body weight. Maintenance of anaesthesia was by intravenous administration of 1:1 mixture of xylazine and ketamine and diazepam

Solano *et al.* (2006) anaesthetized dogs by administration of isoflurane in oxygen flow rate of 15ml /kg body weight/minute.

Dyson (2008) recommended the use of diazepam or midazolam at a dose rate of 0.2-0.5 mg/kg body weight intravenously during induction and maintenance of anaesthesia. The analgesics or anaesthetic could be given as a constant rate infusion (CRI) along with saline or compatible fluids at a rate of 5-20 ml/kg body weight per hour. The suggested dose of ketamine for intra operative CRI was 0.1-0.6mg /kg body weight intravenously.

2.8.2 Surgical site preparation

Penwick (1985) advised removal of hairs with an electrical clipper following administration of anaesthetics. The limb was to be suspended from an intravenous fluid stand or other support throughout the course of preparation so that 360^0 degree of the leg could be clipped scrubbed and prepared. Scrubbing might-be done with chlorhexidine solution.

According to Brown *et al.* (1997), surgical sites clipped before anaesthetic induction were three times more likely to be infected than sites clipped after induction. Risk of wound infection increased with increased duration of surgery.

Weese (2008) suggested that shaving or clipping of the surgical site should not be performed until the day of surgery, ideally right before surgery

2.8.3 Preoperative traction

The fractured limb was secured at the paw and was suspended from the ceiling or an intravenous fluid stand. The limb was pulled up sufficiently tight to allow the limb to be suspended by a portion of the animal's weight (Aron, 1998).

According to Rovesti and Peirone (2002), a significant reduction in time required for surgical intervention was observed by the use of skeletal traction for fracture reduction. Skeletal preoperatory traction permitted an adequate realignment and simplified the application of osteosynthesis, reducing the manipulation of tissue. The factor having the greatest influence on the weight and duration of traction required to obtain fracture reduction was the time interval between trauma and surgical intervention.

The major difficulty in achieving reduction of two piece fracture was counteracting the muscle contraction which was causing bone segments to override. Gradual progressive traction and counter traction over a period of time fatigued the muscles and allowed reduction (Johnson, 2003).

2.8.4 Surgical approaches

2.8.4.1 Humerus

The site of skin incision for approaching the proximal shaft was to be made slightly lateral to the cranial midline of the bone and extended from the greater tubercle of the humerus proximally to a point near mid-shaft. The distal shaft could be accessed keeping craniolateral border of the humerus as the guide for the incision, which commenced at the mid-shaft and ended at the lateral epicondyle. The bone was to be exposed in a manner that ensured preservation of the anatomic and physiologic functions of the area invaded. (Piermattei and Greeley, 1966)

2.8.4.2 Radius and ulna

2.8.4.2.1 Craniomedial approach

Landmarks for the craniomedial incision were the medial epicondyle of the humerus to the styloid process of the radius. Subcutaneous fascia was to be incised along the same line. The brachial artery, vein and median nerve were to be protected at the proximal end of incision (Milovancev and Ralphs, 2004).

Sardinas and Montavon (1997) opined that the length of incision could be varied depending on the location of the fracture. Exposure of distal radius could be improved by incising the fascia of the abductor pollicus longus and retracting this muscle in a craniolateral direction. Care was to be taken to not to severe the cephalic vein as it crossed the distal portion of the radius.

2.8.4.2.2 Craniolateral approach

According to Toombs (2005), the land marks for a craniolateral incision were the radial head and the distal end of the diaphysis. Deep fascia was to be incised along the cranial border of common digital extensor muscle.

2.8.4.3 Femur

The skin incision commenced proximal and slightly cranial to the trochanter major and extended distally just cranial to the shaft of the femur to a point distal to the level of the tibial tuberosity (Eaton-Wells *et al.* 1990).

2.8.4.4 Tibia and fibula

According to Seaman and Simpson (2004), the standard approach to the shaft of tibia involved a medial incision originating at the medial tibial condyle, and terminating at the medial malleolus. The incision should gently be curved to the cranial tibial surface at midshaft before gradually returning medially to terminate at the medial malleolus.

2.8.5 Fracture reduction

Smith (1985) opined that forces necessary to overcome muscle contracture and fibrous callus increased with time.

Denny (1990) found that delayed unions and malunions were the common complications of fractures of radius and ulna in miniature breeds. If nonunion was present, fibrinous and cartilaginous callus between the fragments were to be excised and the fracture surfaces freshened up before reduction.

The primary requisite of reduction technique was that they were gentle and atraumatic, and preserved the remaining vascularity. In the diaphysis of a bone, satisfactory reduction was obtained with the restoration of axial alignment in all the three planes (frontal, sagittal and horizontal). Displacements should be completely corrected in young adults. Anatomic reduction of complex diaphyseal segments should not be attempted where it would be at the expense of the vascularity of the bone (Mast, 1991).

Reduction of comminuted fractures could be challenging because fragmentation often prevented anatomical reduction and required much operative time (Johnson *et al.,* 1998).

Johnson and Hulse (2002a) opined that reduction of oblique fractures were difficult and time consuming since much effort was required to overcome the muscle contraction.

Blaeser *et al.* (2003) observed that a limited enbloc ostectomy and subsequent fracture stabilization with compression plate resulted in rapid bone healing without complications.

For plate and screw application, stability of the reduction was required and mid-diaphyseal fractures could be secured by a contoured plate with a plate holding forceps. Eccentrically placed fractures and distal radial fractures might better be reduced and maintained in reduction by securing a contoured plate to the distal segment and reducing the proximal segment to the plate (Johnson, 2003).

Jackson and Pacchiana (2004) opined that in order to restore alignment in a malunion an osteotomy should be performed and then stable fixation was to be provided.

According to Piermattei *et al.* (2006), transverse fractures could be reduced by elevating the fractured bone ends out of the incision and bringing them in contact with each other. Alternatively an osteotome, bone skid, periosteal elevator or scalpel handle could be used to lever the bone segments to alignment. Application of a bone holding forceps at an angle to the fracture line and gentle manipulation was a method of fracture reduction in oblique fractures.

2.8.6 Contouring of plates

According to Jones (1994), the plate should be carefully contoured to match the bone surface to ensure the maintenance of accurate reduction. Plate bending pliers were available for this purpose. If practicable, prior moulding of the plate to the radiograph of intact bone might save considerable intra operative time and thereby reduce the risk of infection.

Conzemius and Swainson (1999) opined that bone plates that were well contoured had a less than 30% contact with the bone. The two reasons for contouring the plate were to protect the screws from shear and to prestress the plate. A well-contoured bone plate should result in the fracture ends remained aligned during screw tightening. To maintain mechanical strength of plate, it should be bent between screw holes while creating a gentle bend over a greater area of the plate as opposed to a large bend at a single location of the plate.

2.8.6.1 Contouring of plates in fractures of humerus

Marcellin-Little (1998) opined that contouring of stiff plates to the anatomical curvatures of humerus was difficult.

Tomlinson (2003) observed that the medial approach to humerus was typically used for bone plating because of the shape of the medial side of the humerus allowed minimal contouring of the plate.

Simpson (2004) found that medial approach was less favourable because of the concern for damage to the brachial vessels and nerves in the area and because it was widely accepted that the craniolateral aspect of the humerus was the tension band side of the bone.

According to Turner (2005), the medial cortical surface of humerus was relatively straight while the cranial and lateral surfaces were curved and had more irregularities. Thus placement of plates along the cranial and especially lateral cortices required more bending of the plate to contour it to the bone surface.

2.8.6.2 Contouring of plates in fractures of radius and ulna

Sardinas and Montavon (1997) opined that plates should be contoured to the radius before application. A slight bow could be placed on the plate to confirm it to the cranial curvature of the radius. Using a lateral radiograph of the contralateral limb to help pre-contour the plate before surgery was recommended.

2.8.6.3 Contouring of plates in fractures of femur

When a plate was applied as a compression plate in femoral fracture, it should be contoured so that the plate remained slightly offset from the surface of bone (1-2mm) at the fracture line. If the plate was contoured to confirm accurately to the bone surface, asymmetric loading of the fracture line would occur (Hulse *et al.* 2005).

2.8.6.4 Contouring of plates in fractures of tibia

Accurate contouring of a stiff bone plate to fit comminuted or multiple fractures in tibia was difficult unless the fracture could be anatomically reconstructed and secured with screws or wire. Inappropriate contouring would result in mal-alignment (Dudley *et al.* 1997).

Glyde and Arnett (2006) advised intraoperative contouring of the bone plate in a mediolateral and craniocaudal plane prior to application to the bone due to the sigmoid shape of the tibia. When viewed from a medial aspect, the plate was applied to the line of 'best fit' and typically required placement along the caudal edge of the proximal third. Slight twisting of the plate was usually necessary if the plate was applied to the full length of the tibia, to account for the 10-15° of tibial torsion.

2.8.7 Prestressing of plate

According to Schatzker (1991), leaving a gap in the opposite cortex would cause micro movements and decrease the stability of fixation in compression plating resulting in bone resorption. Compression of far cortex could be achieved by overbending the plate, which then pressed against the bone and acted like a spring to close the gap in the far cortex. Overbending could be used only when dealing with two fragment fractures and in complex fractures, it might often jeopardize reduction.

If a straight plate was applied to a straight bone, a gap occurred in the far cortex as tension was applied to the plate. To overcome this, plate was to be pre-bent to a slight convexity at the fracture site (DeYoung and Probst, 1993).

2.8.8 Application of plates

According to Nunamaker (1985), plates were to be placed on the tension band side of bones to prevent failure. The tension band surfaces in the dog were on the lateral aspect of the femur, cranial lateral aspect of the tibia, the anterior aspect of the humerus, anteriolateral aspect of the radius and caudal aspect of proximal ulna.

Wallace *et al.* (1992) reported that short length of the distal fragment which might not allow placement of enough screws and interference of extensor tendons were the major difficulties in applying bone plates for fixation of distal radial fractures.

DeYoung and Probst (1993) observed that plates were not always applied to the theoretical tension band side of weight bearing bones. Plates were usually applied to medial aspect of tibia, because the lateral approach was more difficult.

Sardinas and Montavon (1997) found that medial plate application in radial fractures was technically easier to do than cranial plate application; the technique avoided the extensor tendons, and permitted greater versatility in the selection of smaller plates for the fixation of distal radial fracture

Boudrieau (2003) stated that plates were usually applied to the cranial surface (tension band surface) of the radius. Alternatively, a plate might be applied to the medial surface of distal radius. Medial plate application provided superior screw purchase in the thicker medio-lateral cortices, closer placing of screw holes to allow a greater number of screws and avoidance of the extensor tendons. The axial stiffness provided was comparable to cranial plate application.

Neutralization plate was applied on the tension side of the bone to neutralize torsional, bending, compressive, and distraction forces on fracture lines that had been stabilized by inter-fragmentary compression supplied by lag screws and cerclage, hemicerclage or inter-fragmentary wire (Piermattei *et al.* 2006).

2.8.9 Plate fixation

2.8.9.1 Dynamic compression plating

Nunamaker (1985) described the procedure of dynamic compression plating. Use of a power drill was advised to prevent wobbling. Even with a power drill, it was helpful to use drill guides to prevent wobbling. Pre-tapping of the drill hole allowed screws to be inserted with less torque.

If the thread was stripped or damaged during the tapping process, use of an oversized tap or screw was advised or a new location selected for insertion of a screw of the original size (Egger and Whittick, 1990).

DeYóung and Probst (1993) opined that screws in a fracture or fissure line might result in distraction of fragments, worsening of the fissure or stripping of screw threads. Leaving a screw hole empty or use of a short screw were the solutions.

If there was a failure to obtain purchase with the screws, the available options suggested by Turner (2002) were: redirect the screw insertion angle, use a larger screw size, use a different bone site to achieve similar fixation in bone or application bone cement in to the screw hole.

According to Stiffler (2004), a minimum of two screws, but preferably greater than three screws should be engaged in both the proximal and distal main bone segments.

During drilling and screw fixation, the reduction could be maintained by securing the plate to the proximal segment with a plate holding forceps (Houlton and Dunning, 2005)

2.8.9.2 Neutralization plating

Denny (1991) found that a neutralization plate was applied after lag screws had been used to reconstruct the shaft in an oblique or comminuted fracture.

According to Hulse *et al.* (1997), multiple fragments in comminuted fractures could be anatomically reconstructed with either lag screws or cerclage wire and then plates applied to neutralize the disruptive forces.

Neutralization plating was used when no tension was applied to the plate during the application of screws. A DCP might be used, but all of the screws were placed in a neutral position. In effect, the plate was used to protect the fragment reconstruction performed with other mechanically weaker implants like combination interfragmentary pins, wires, or screws and the plate was applied to the help neutralize the forces of fracture. Screw placement through the bone plate usually began at the most proximal and distal holes of the plate. Screws were then sequentially placed in the bone fragments towards the fracture site (Conzemius and Swainson, 1999).

Saravanan *et al.* (2002) observed initial stability in neutralization plate cerclage wire combination.

A neutralization plate was similar to a positional screw in that it applied no compression to the bone but simply held the fragments in reduction. It was less stable because more bending forces were absorbed by the plate (Stiffler, 2004).

2.8.10 Intraoperative lavage

During drilling, constant flushing with balanced saline or lactated ringer solution under pressure helped to maintain a clear field free of bone debris, thus minimizing the possibility of infection (Egger and Whittick, 1990).

2.9 POSTOPERATIVE CARE

2.9.1 Postoperative immobilization

Although internal fixation allowed early pain free movement refractures might occur through overuse of the limb during recovery period (Hunt *et al.* 1980)

Chapman *et al.* (1989) observed that when patient compliance was poor, protection of the limb in a long plaster cast was necessary after plating until the fracture had united.

Langley-Hobbs *et al.* (1996) defined the ideal properties of a cast material. Plaster of paris had the advantages like easiness in application, radiolucency, and easy removal. The disadvantages were prolonged drying time, least resistance to buckling and generation of lot of dust.

Because healing with a plate and screw was meant to occur by primary bone healing, a true race occurred between fracture healing and metal fatigue with subsequent implant failure. Since primary healing was slower, the implants must be protected with controlled exercise and an appropriate dressing (Leeds, 1998)

Weinstein and Ralphs (2004) opined that Robert Jones bandage restricted the motion and soft tissue swelling and was a very effective method of temporary stabilization especially for fractures distal to elbow and stifle postoperatively.

2.9.2 Postoperative pain management

According to Millis (2004), it was vitally important that the dog be adequately treated for pain to allow early, active use of the affected limb.

From an evaluative study Mondal *et al.* (2005) found that tramadol at the dose rate of 2 mg/kg body weight had a prolonged effect than meloxicam or ketoprofen when used for postoperative analgesia.

McMillan *et al.* (2008), administered tramadol at three different dose levels (1, 2 and 4 mg/kg) and found that it was a safe analgesic in dogs.

2.9.3 Postoperative antibiotic therapy

According to Carter (1966), if there had been a break in the skin either due to an open fracture or due to surgical procedure, antibiotics had to be administered for four to five days.

Rochat (2001a) recommended use of antibiotics in clean orthopaedic surgical procedures with implant placement and severe trauma especially when they last for more than two hours. A first generation cephalosporin was the drug of choice.

Agrawal *et al.* (2008) opined that due to the use of implants for open reduction and internal fixation, which were foreign bodies to the body, orthopaedic trauma surgery was at a grave risk of microbiological contamination and infection. Gram negative infections were emerged as the major threat in orthopaedic cases and ceftriaxone and cefaperazone were found to be the most effective antibiotics against them.

2.10 EVALUATION OF THE STUDY

Evaluation of bone healing included both clinical findings and radiographic changes (Doyle, 2004).

2.10.1 Clinical evaluation

Care must be taken to differentiate clinical union *i.e.* when stabilization was present at the fracture site, from complete healing which was only attained when remodeling was complete and medullary cavity re-established (Hickman, 1966).

Sumner-Smith (1974) opined that the clinician might be totally misled by the confusing evidence presented in clinically healing fractures. Absence of pain and demonstrable movement of the fragments might lead to premature implant removal in the absence of a radiograph.

2.10.1.1 Pain at fracture site

The patient must be carefully assessed to determine if excitement, whining or agitation was due to pain, dysphoria or disorientation. When in doubt, pain should be assumed, and the response to treatment defined if this judgment was correct (Dyson, 2008).

2.10.1.2 Functional limb usage

Braden and Brinker (1973) evaluated the healing of femur fractures on a weekly interval by assessing the functional limb usage by a 1 to 4 grading system. Fractures fixed with bone plates regained normal full function of the injured limb in about 3.5 weeks. They concluded that postoperative clinical use of limb was associated with both the implanted device and bone healing. Bone plates were superior in providing early postoperative weight bearing.

Ayyappan et al (1999) observed partial weight bearing in a dog following plate fixation for comminuted tibial fracture in a dog from the second postoperative day onwards.

Yuvraj *et al.* (2007) observed complete weight bearing from second day onwards in dogs with femoral diaphyseal fractures stabilized with DCP.

2.10.2 Radiographic evaluation

Braden and Brinker (1976) observed that radiographic evaluation could be done in series after internal fixation. Immediate postoperative radiographs could be used to evaluate surgical reduction, alignment and fracture gap. Subsequent serial radiographs might be used to monitor alignment, callus formation and fracture gap if any. The degree or lack of stability could be determined by the amount of callus.

Hunt *et al.* (1980) opined that the errors in the reduction and stabilization of fractures emphasize the importance of postoperative radiographs to show faults in the application of the implant or the alignment of the fragments which could then be corrected immediately.

Postoperative radiographic monitoring of the fracture should be carried out in every two weeks. Two views of the fracture site were necessary. Radiographs were to be examined for healing response (Egger and Whittick, 1990).

Dudley *et al.* (1997) observed that varus or valgus mal-alignment could be determined by measuring the angle between lines drawn perpendicular to, and bisecting the proximal aspect of joint surface and proximal portion of the medullary canal with lines drawn perpendicular to and bisecting the distal aspect of the joint surface and the distal portion of the medullary canal on craniocaudal postoperative radiographs of the fractured tibia. Cranial or caudal mal-alignment were determined measuring the angle between a line drawn parallel to the proximal fragment and a line drawn parallel to the distal fragment on lateral postoperative radiographs of the fractured limb.

According to Sande (1999), anatomical reduction and stable fixation of fractures resulted in primary healing which was evidenced in radiograph as apposition of cortical margin and contact between medullary cavities of the reconstructed ends. During secondary bone healing, approximately five to seven days following trauma, the fracture margins lost sharpness and were indistinct or smudged. The bony callus required 10 to 12 days to acquire adequate mineral so that it could be seen on radiographs.

Langley-Hobbs (2003), found that a thorough assessment of the immediate postoperative radiograph could be aided by considering the 'four A's- apposition, alignment and angulation and apparatus. Follow up radiographs should be evaluated both in isolation and in comparison with the previous films. A thorough evaluation could be assisted by considering the 'six A's: - apposition, alignment and angulation, apparatus, activity and architecture.

Piermattei *et al.* (2006) indicated that it was important to be able to interpret the biological responses with rigid fixation where primary or direct bone union was anticipated. Development of a cloudy irritation callus was a warning sign and indicated some movement occurring at the fracture site and potential for delayed or malunion.

According to Rovesti *et al.* (2006), radiographs taken immediately after the surgical procedures could be used to evaluate the contact between the fracture fragments and the axial alignment of the treated limb could be graded using the following scale

1. Excellent : 90% to 100% contact between fracture fragments and axial mal-alignment in any plane of less than 5^0
2. Good : 50% to 89% contact between fracture fragments and axial mal-alignment in any plane of less than 10^0
3. Fair : 10% to 49% contact between fracture fragments and axial mal-alignment in any plane of less than 30^0
4. Poor: 0 to 9% contact between fracture fragments and axial mal-alignment in any plane of 30^0 or more.

Risselada (2008) observed that during direct fracture healing after plate osteosynthesis, no or a minimal amount of periosteal callus reaction would be present. Healing was radiographically evident as a reduction of the fracture gap. Healing of the fracture was confirmed when three to four cortices were restored with iso-opaque bone evident on orthogonal radiographs.

2.11 COMPLICATIONS

2.11.1 Self mutilation of cast

Following internal fixation, Hickman (1966) advised support of leg with pressure bandage to control swelling and oedema which was to be replaced by a plaster cast after 48 hours. The dog was to be confined in a small ground level kennel. If the animal was trying to mutilate the bandage putting an Elizabethan collar or sedation was essential.

Roush and McLaughlin (1998) advised the use of Elizabethan collars to prevent coaptation damage when the animal was not directly observed. External coaptation or external fixators should be protected from damage by the patient.

2.11.2 Wound dehiscence

Eugster *et al.* (2004) observed that postoperative infection and inflammation was associated with six significant factors; duration of anaesthesia, postoperative intensive care unit stay, wound drainage, increasing patient weight, dirty surgical site and antimicrobial prophylaxis.

Weese (2008) opined that surgical site infection was an important complication of orthopaedic surgery.

Following plate fixation in tibial fractures, closure of soft tissues was often difficult due to the bulk of the appliance and lack of soft tissue required to cover the plate. Plate should be buried as thick a layer of soft tissue as possible. Transposition and freeing of up of soft tissues might be necessary to avoid tension (Eaton-Wells *et al.* 1990).

2.11.3 Breakage of cerclage wire

Stiffler (2004) observed that the most common complication of orthopaedic wiring was breakage and loosening. Cerclage wires provided only minimal resistance to forces acting on the fracture. When broken, they might cause significant morbidity and required removal.

Saravanan *et al.* (2002) observed that when used to reconstruct fragments in neutralization plating, cerclage had only poor performance.

According to Glyde and Arnett (2006), cerclage wire had limited indications as an adjunct to the repair of tibial fractures for both biological and biomechanical reasons. Lag screws provided superior interfragmentary compression with usually less soft tissue damage. Lack of soft tissue on the craniomedial aspect of the tibia meant that placement of twist cerclage wires via the standard craniomedial approach required bending of the twists to lie flat and consequently knot tension was usually not maintained. Use of loop cerclage rather than twist cerclage would overcome this problem and was strongly recommended.

2.11.4 Plate bending and screw loosening

According to Jones (1994), most patients would tolerate a small amount of shortening or angular mal-alignment. Rotational deformity created significant cosmetic and functional deformities in the distal humerus, femur and in particular, the tibia.

Roush and Mc Laughlin (1998) opined that motion at fracture site could lead to implant loosening.

Premature loosening of screws and implant failure occurred in moderate and prolonged stress especially when implant selection and technique was poor resulting in micromotion. In such cases, bone resorption and eventual implant loosening resulted (Johnson and Hulse, 2002).

Turner (2002) observed that plate application errors were due to inappropriate selection of the proper plate function, incorrect anatomic bone site, failure to span a sufficient length of bone, and failure to securely fit the plate to proximal and distal bone ends. Failure to obtain proper plate contour to the bone surface would result in mal-alignment, impaired joint and limb function and possible impaired bone healing.

Piermattei *et al.* (2006) found that loose screws in bone plates could be a cause for nonunion and plates might be salvaged by replacing with larger screws if the plate holes accepted them or else cortical threads might be replaced by cancellous threads.

2.12 PLATE REMOVAL

Pullen (1998) advised removal plates especially in extremity fractures in which motion and weight bearing played pivoted roles. Exceptions were malunion or delayed union, distal radial fractures in toy breeds and geriatric patient.

Unexpected lameness of the limb with the plate was an indication of removal of plate (Conzemius and Swainson, 1999).

Rochat (2001b) opined that plates could be usually left in place, even after completion of healing and needed to be removed only if they interfered with tendon movement, caused lameness due to cold sensitivity, in infected fractures or resulted in secondary osteoporosis.

Plate might be removed when they were applied to areas with limited soft tissue covering such as the radius and ulna because cold transmission might cause lameness (Johnson and Hulse, 2002).

In cases of osteomyelitis, Jackson and Pacchiana (2004) advised removal of all implants after healing of the fracture to fully eradicate the infection.

Materials and Methods

3. *MATERIALS AND METHODS*

3.1 SELECTION OF ANIMALS

The study was conducted in clinical cases of long bone fractures in dogs presented at the surgery units of University Veterinary Hospital, Kokkalai, Thrissur and Veterinary College Hospital, Mannuthy from October 2007 to March 2008. Dogs presented with the history of lameness were subjected to detailed clinical and orthopaedic evaluation for the presence of fractures. Those cases of fractures of long bones were subjected to radiography for confirmation and for determining the characteristics of fractures like location, type and concurrent injuries. A total of eight dogs with diaphyseal fractures were selected irrespective of breed, sex, age or the limb affected and the dogs were serially numbered from A1 to A8.

3.2 BROAD OUTLINE OF WORK

The dogs with long bone fractures were subjected to detailed clinical and radiographic evaluation which was followed by collection of blood samples for haematological and serum biochemical evaluation. After confirming the fitness of the animal for surgery, appropriate bone plate was selected on the basis of size of the animal, body weight and location of fracture. Following adequate preoperative preparation of the patient and general anaesthesia, the fractured fragments were exteriorized surgically and the plate fixed in position following standard Association for Osteosynthesis/ Association for the study of internal fixation (AO/ASIF) principles. Suitable external supporting bandages were applied after closure of surgical wound. Clinical, radiological, haematological and serum biochemical evaluation were conducted preoperatively, immediate postoperative day, and thereafter on the 15th, 30th and 60th postoperative days.

3.3 SIGNALMENT AND ANAMNESIS

Signalment and historical data pertaining to each case were recorded.

3.4 PREOPERATIVE CONSIDERATIONS

3.4.1 Evaluation of the patient

Dogs with fractures resulting from severe trauma such as automobile accidents were thoroughly investigated for hidden injuries of the core body systems.

3.4.1.1 Physical examination

The general body condition and clinical signs exhibited by each dog were recorded. General clinical examination with palpation, percussion and auscultation was carried out to evaluate the body systems. The affected limb was carefully and gently handled and examined for obvious abnormalities like pain, crepitus, bruises, swelling, lacerations or the presence of deep wounds. Dehydration status was evaluated and corrected if present.

3.4.1.2 Orthopaedic examination

General orthopedic examination of all the patients was conducted and this included individual observation, palpation and manipulation, assessment of neurological function and range of motion. Each patient was observed during ambulation and at rest for evaluation of the functional limb usage. During ambulation, the gait, locomotion, adaptation and equilibrium of ambulation were noted. Abnormalities like shortened stride, dragging of the toe nails, toeing in, toeing out, limb circumduction, stumbling and 'head boob' (bobbing motion of the head that occurred with forelimb lameness) were recorded.

3.4.1.2.1 Evaluation of functional limb usage

Functional limb usage was assessed by observing the animal from a distance, allowing it to walk. Lameness was quantified by the following 0 to 10 grading system developed by Sumner–Smith (1993) and the scores were used for evaluation of the functional limb usage:

0. Sound
1. Occasionally shifted weight
2. Mild lameness at a slow trot, none while walking
3. Mild lameness while walking
4. Obvious lameness while walking, but placed the foot when standing

5. Degrees of severity (moderate lameness, still placed foot while standing)
6. Degrees of severity (moderate lameness tending to shift weight off the limb when standing)
7. Degrees of severity (severe lameness)
8. Degrees of severity (severe lameness, intermittent carriage of limb)
9. Places toe when standing, carries limb when trotting
10. Unable to put the foot on ground

3.4.1.2.2 Neurological examination

Conscious proprioception was tested by knuckling the dog's paw to rest on the dorsum of the foot while supporting its body and seeing whether the animal immediately corrected the posture.

3.4.2 Preoperative radiographic assessment

After locating the area of the fracture based on the history and physical examination, plain lateral radiograph of the affected portion of the limb was taken. Wherever possible, two orthogonal views of the affected bone and adjacent joints were included in the radiograph

3.4.3 Physiological parameters

Rectal temperature (°C), pulse rate (per minute), respiratory rate (per minute) and colour of visible mucous membrane were recorded preoperatively, immediate postoperative day and thereafter on 15^{th}, 30^{th} and 60^{th} days.

3.4.4 Haematological parameters

Blood samples were collected preoperatively, immediate postoperative day and thereafter on 15^{th}, 30^{th} and 60^{th} days for estimation of haemoglobin concentration, volume of packed red cell (VPRC), erythrocyte sedimentation rate (ESR), total leukocyte count (TLC) and differential leukocyte count (DLC). Ethylene diamine tetra acetic acid (EDTA) was employed as the anticoagulant (Schalm *et al.*, 2000).

3.4.5 Serum biochemical evaluation

Blood samples were collected without anticoagulants for separation of serum. Serum alkaline phosphatase, serum calcium and phosphorus levels were estimated preoperatively, immediate postoperative day and thereafter on 15^{th}, 30^{th}

and 60^{th} days. Alkaline phosphatase was measured using Echolac alkaline phosphatase kits supplied by Merck specialties Pvt. Ltd., Mumbai, using a semiautomatic analyzer, Secomam Basic as per manufacturer's instruction. Serum calcium and phosphorus were estimated calorimetrically in the same semi auto analyzer using the kits supplied by Agappe Diagnostics Pvt. Ltd., Ernakulam.

3.4.6 Preoperative stabilization of the patients

Those dogs with potentially unstable or comminuted fractures with a tendency to become open were given emergency priority. Debridement and thorough cleansing of wounds were undertaken in animals presented with open wounds and surgery undertaken on an emergency basis.

Preoperative analgesics were used in dogs which exhibited severe pain at the time of presentation.

Antibiotics were administered prophylactically in dogs which showed signs of systemic involvement like pyrexia or presented with open wounds.

In dogs where elective surgery was undertaken, the fractured limbs were temporarily immobilized with plaster of paris (POP) cast or Robert John's bandage.

Prior to surgery, food and water were withheld for twelve hours.

3.5 DECISION MAKING AND IMPLANT SELECTION

3.5.1 Fracture assessment score

The selection of functional mode of application of plate (compression, neutralization or buttress) was done based on a fracture assessment score. Clinical, biological and mechanical factors formed the basis of the grading system that ranged from 0 to 10 (Fig. 3). The individual score for each factor under consideration was summed up and divided by total number of factors considered to give the score of the patient.

Low score (0 to 3): This meant the animal was in high risk group. Implants were used to bridge fractures and therefore must have sufficient strength to prevent permanent bending or breakage. Plates were used in buttress mode.

Moderate score (4 to 7): Overlapping biological and mechanical factors affected healing and implants selection. Less implant strength and endurance were required and plates were used to function in neutralization mode.

High score (8 to 10): Transverse or short oblique fractures. Mechanical assessment indicated minimal implant stress caused by load shared and biological assessment indicated enhanced healing potential. Immediate load sharing between bone-implant construct and rapid bone union was expected. Plates were used in compression mode. The factors considered and the score assigned to each of them were summarized below:

MECHANICAL FRACTURE ASSESSMENT							
High risk factors	Score	Medium risk factors	Score	Moderate risk factors	Score	Low risk factors	Score
Non-reducible fragments	1-2	Reducible fragments	5-6	-	-	Transverse	8.5-10
Multiple limb injury	1-3	Pre existing clinical diseases	4-6.5	-	-	Single limb	8.5-9.5
Giant breed	1-2.5	Large dog	5-6	-	-	Toy breed	8.5-9.5
BIOLGICAL FACTORS							
Old patient	1-2	Middle age	4.5-5.5	Young adult	6.5-7.5	Juvenile	9-10
Poor health	1-2	-	-	-	-	Excellent health	8.5-10
Poor soft tissue envelope	1-3.5	-	-	-	-	Good soft tissue envelope	7-10
Cortical bone	1-2	-	-	-	-	Cancellous bone	6-10
High velocity injury	1-3	-	-	-	-	Low velocity injury	6-10
Extensive approach	1-3	-	-	Mini approach	6-7.5	Closed	9.5-10
CLINCAL FRACTURE ASSESSMENT							
Poor client compliance	1-3	-	-	-	-	Good client compliance	7.5-10
Poor patient compliance	1-3	-	-	-	-	Good patient compliance	7.5-10
Wimp	1-2	-	-	-	-	Stoic	9.5-10
High comfort level required	1-3.5	-	-	-	-	Comfort level not a consideration	6.5-10

(Johnson and Hulse, 2002a)

3.5.2 Preoperative fracture plan

Preliminary selection of implants was based on the size of the patient, body weight and location of fracture in the bone. The most consistent factor used for choosing the size of implant was weight of the patient (Piermattei *et al.*, 2006).

In order to determine the correct size of screws and plates required to stabilize each fracture, a preoperative fracture plan was drawn consulting the radiographs. A radiograph of contra lateral limb was taken whenever possible and used as a template for reducing the fracture. This provided a mirror image of the fractured bone which was flipped over and the outlines traced on a butter paper. The tracing was placed over the radiograph of the fractured bone and aligned to the intact shaft of the fracture. The proximal fracture line was traced. This process was repeated for the distal fragment aligning the intact edges with the same contour on the tracing (Fig. 4).

AO/ASIF standard implant reference chart based on specific bones and weight of the patient was further consulted in selecting the precise plates and screws (Fig. 5).

3.5.2.1 Screws

Non self tapping cortical screws of thread diameter 2.7mm and 3.5mm were used for the study and they were utilized as plate screws (Fig. 2). Screw sizes greater than 25-30% of diameter of the bone were avoided. The screw length was preliminarily decided from the fracture plan and confirmed by referring the AO/ASIF standard screw and drill bit chart (Fig. 6). However, the exact length was assessed during plate fixation by measuring the drill holes with a depth gauge. 1-2mm length was added to the measured distance to ensure adequate screw purchase in to the far cortex. The drill bit diameter for 2.7mm screw was 2.0mm and that for 3.5mm was 2.5mm and corresponded to the inner core diameter of screws.

3.5.2.2 Plates

Plates used in the study were 2.7mm reconstruction plates and 2.7mm and 3.5mm dynamic compression plates (Fig. 2).

3.6 SURGICAL TECHNIQUE

3.6.1 Anaesthesia

The surgery was performed in all dogs under general anaesthesia. With the exception of Dog No: A6 which was pregnant, all other dogs were premedicated with atropine sulphate[1] at the rate of 0.045mg/kg body weight administered intramuscularly. After ten minutes xylazine[2] was administered intramuscularly at the dose rate of 1mg/kg body weight. After 15 minutes anaesthesia was induced by intramuscular administration of ketamine hydrochloride[3] at the dose rate of 10mg/kg body weight. Anaesthesia was maintained by intravenous administration of a mixture of equal volumes of xylazine and ketamine in small increments of 0.2ml to effect and intravenous administration of diazepam[4] at the dose rate of 0.2mg/kg body weight.

The pregnant bitch (Dog No: 6) was premedicated with xylazine at the dose rate of 0.5mg/kg body weight. After ten minutes, anaesthesia was induced by administering propofol[5] at the dose rate of 4mg/kg body weight by intravenous bolus injection. Endotracheal intubation was performed and anaesthesia maintained by a mixture of 2.5% isofluorane[6] in oxygen administered through a Bane's closed circuit system.

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1. Atrowok injection : Atropine sulphate 0.6 mg/ml, Wockhardt Ltd., Mumbai (1ml ampoule).
2. Xylaxin injection : Xylazine hydrochloride 23.32 mg/ml (equivalent to 20 mg xylazine), Indian Immunologicals, Hyderabad (10 ml vial).
3. Ketmin50 injection : Ketamine hydrochloride IP.50 mg/ml, Themis Medicare Ltd., Mumbai (10ml vial).
4. Calmpose injection: Diazepam IP 5mg/ml, Ranbaxy Laboratories Ltd., Baddi Dist., H P. (2ml ampoule)
5. Propofol injection : Propofol 10 mg/ml, Neon Labs, Mumbai (20ml vial)
6. Forane : Isofluorane, Abbot Lab, Kent, U.K (250ml bottle)

3.6.2 *Preparation of site*

Surgical site preparation was undertaken after induction of anaesthesia to reduce the risk of surgical site infection. The hair clipping was done in an area outside the operating environment using an electrical clipper. The hair was removed circumferentially from a wide area extending from the carpus or tarsus distally to dorsal and ventral midline proximally. The foot and foot pads were covered with a piece of gauze and tape and the limb suspended from an intravenous fluid stand so that 360^0 of the leg could be clipped, scrubbed and prepared (Fig. 7). The clipped area was washed with chlorhexidine and Cetrimide solution[7] and water for five to ten minutes. The scrubbing was performed in a centripetal manner starting from the incision site and progressing towards the periphery. The prepared site was then covered with a sterile drape before transporting the animal into the operation theatre.

3.6.3 Traction

The animal was controlled in dorsal recumbency. A piece of tape was tied around the paw of the affected limb and the limb suspended from an intravenous fluid stand so that the animal was slightly raised over the table (Fig. 8). In this way traction was applied for 10 to 30 minutes.

3.6.4 Secondary scrubbing

While applying traction, a secondary scrubbing with povidone iodine scrub solution[8] was done and after completely removing the scrub solution, the entire prepared area was painted with tincture iodine centripetally from the line of incision.

3.6.5 Positioning for surgery

The animal was positioned on the table so as to expose the fracture site for open reduction and internal fixation. Standard quarter towel and fenestrated draping techniques were used to create a sterile field to work within.

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7. Suphalon : Chlorhexidine and Cetrimide 2% w/v Southern Union Pharmaceuticals, Thrissur

8. Germiclean : Povidone iodine surgical scrub solution IP 7.5%, Torrel Cosmetic Pvt. Ltd., Ahmedabad (500ml bottle).

3.6.6 Surgical approaches

3.6.6.1 Humerus

The diaphysis of the bone was approached by a craniolateral incision along a line slightly lateral to the cranial midline and starting from the greater tubercle and ending at the lateral epicondyle (Plate 1-A). The triceps and brachialis muscles were retracted caudally and biceps, superficial pectoral and brachio cephalicus muscles were retracted cranially. The radial nerve, under cover of brachialis muscle was retracted cranially for better exposure of distal shaft.

3.6.6.2 Radius and ulna

3.6.6.2.1 Craniomedial approach

The medial epicondyle of the humerus and styloid process of the radius formed the land marks (Plate 1-B1). The incision commenced at the styloid process and continued proximally one fourth to one half of the length of the bone. The cephalic vein which crossed beneath the distal portion of the skin incision was protected. Deep fascia was incised between the extensor carpi radialis and pronator teres muscle proximally at the proximal end of the incision and continuing dissection along the caudal edge of extensor carpi radialis muscle distally. The extensor carpi radialis was pulled cranially and flexor carpi radialis deflected caudally to maintain exposure to the radius. Elevation of the pronator teres muscle increased proximal exposure.

3.6.6.2.2 Craniolateral approach

The land marks for craniolateral approach were the radial head and distal end of the diaphysis (Plate 1-B2). Deep fascia was incised along the cranial border of the common digital extensor muscle. Caudal retraction of the common and lateral digital extensor muscles and cranio-medial retraction of the extensor carpi radialis exposed most of the shaft of the bone laterally. Incision through the abductor pollicis longus muscle near its origin in ulna freed the muscle for cranio-distal retraction.

3.6.6.3 Femur

The skin incision was made on the craniolateral border of the shaft of bone from the head of greater trochanter to the level of patella (Plate 1-C). The superficial leaf of the fascia was incised along the cranial border of the biceps femoris muscles for the length of incision. The biceps was retracted caudally to expose the vastus lateralis muscles. The fascial septum of vastus lateralis was incised as it inserted at the caudal lateral border of the femur. The vastus lateralis was reflected from the surface of the femur to expose the femoral diaphysis.

3.6.6.4 Tibia

A cranio-medial skin incision was made parallel to the tibial crest and extended to the required length. The incision gently curved to the cranial tibial surface at midshaft before gradually returning medially to terminate at the medial malleolus (Plate 1-D). The dissection was continued through the fascia, avoiding the medial saphenous vein and nerve crossing the middle to the distal third of the tibial diaphysis.

3.6.7 Fracture reduction

Transverse/short oblique fracture was reduced by elevating the fractured bone ends out of the incision and bringing them into contact with each other. Pressure was slowly applied to replace the bone in normal position (Plate 2-A). Use of a Hohman's retractor or BP handle as a lever assisted in reducing over-riding fragments. Alternate method of holding the fragments with two bone holding forceps and gradual application of distraction was also used in oblique fractures. Multiple fracture fragments were reduced by applying a contoured plate over one fragment and then securing the loose fragments with a cerclage wire. The two piece fracture was then aligned to the other segment by careful distraction and manipulation (Plate 2-B). When overriding muscle forces were high, a bone holding forceps was applied at an angle to the fracture line and manipulated by finger pressure to aid in reduction (Plate 2-C). Eccentrically placed fracture like transverse distal radial fracture was better reduced and maintained in reduction by securing a contoured plate to the distal segment and reducing the proximal segment to the plate. If nonunion was present, fibrinous and cartilaginous callus between the fragments were excised and the fracture surfaces freshened up before reduction (Plate2-D).

3.6.8 Contouring of the plate

The plate was contoured to the original shape and curvature of the bone. It was bent and twisted between the screw holes to fit the bone using two bending irons. In tibial fractures, pre-contouring of the plate to the radiograph of contralateral limb was done wherever possible to ensure that the S shaped curve of tibia was reproduced without error.

3.6.9. Prestressing of the plate

Prestressing of the plate was done to minimize the gap on the far cortex and to assist in compression when the screws were finally tightened. After contouring the plate, a small kink was made directly over the fracture site to leave a one millimeter gap between the plate and bone at the fracture site. Tightening the pre-stressed plate caused additional compression in the cortex opposite the plate. When comminution was present on the side opposite the plate, pre-bending was avoided.

3.6.10 Application of plates

In both dynamic compression and neutralization plating, plates were applied to the tension band surface of the fractured bone.

For humeral fracture the plate was placed in the cranial surface.

For radius and ulna fractures, only the radius was stabilized with plates applied in two ways. In one case the plate was applied in the cranial surface. The problems faced were short length of distal fragment which did not allow placement of enough screws and plate interfered with the function of extensor tendons. So as a remedial measure, medial plate application was tried which allowed placement of more screws per fragment (Wallace *et al.*, 1992).

In case of femur, plate was fixed in the tension side (ie. lateral) and applied to function as a compression plate. Tibial fractures were stabilized by applying plates in the craniomedial aspect.

The plates were selected in such a way as to have at least four cortices or two fully threaded screws in either side of the fracture site.

3.6.11 Plate fixation

3.6.11.1 Dynamic compression plate

The contoured plate was placed on the fracture site and centered over the fracture so that a hole was drilled about one centimeter from its fractured end in neutral position using the neutral guide. The drill bit diameter corresponded to the inner core diameter of the screw used. A low speed high torque Bosch power drill was used to drill the holes (Fig. 1). The plate was placed over this hole, depth of the hole measured and tapped through both cortices. The correct length screw was chosen and inserted loosely until it began engaging the hole in the plate. The fracture was reduced and held with bone holding forceps so that plate was aligned parallel to the long axis of the bone. A hole was then drilled through the bone using the eccentric guide in the screw hole nearest the fracture site in the other fracture fragment with arrow of the guide pointed towards the fracture site. This hole was also measured tapped and screw of proper size inserted. The bone clamp was removed and upon tightening both of these first screws alternatively, the fracture gap was closed and segments reduced with good stability. The remaining holes on both sides of the fracture site were drilled using the neutral drill guide. These holes were measured tapped and screws inserted. Alternate tightening of the screws from the centre outward ensured that all screws were tight. This procedure was repeated two or three times (Nunamaker, 1985).

3.6.11.2 Neutralization plates

Bone plate was used to bridge the area to neutralize the forces that acted to collapse the fracture. Cerclage wire was used to anatomically reconstruct the fracture and provide interfragmentary compression. The neutralization plate was applied to the tension surface of bone after contouring it to the anatomic surface of the bone. A minimum of six cortices were engaged in each side of the fracture. All screws were inserted in the neutral position, beginning from the end of the plate and working towards the centre. Those screw holes lying on the fracture line were left empty (Plate 3).

3.6.12 Intraoperative lavage of surgical site

Frequent lavage of surgical site was performed with gentamicin[9] mixed normal saline which was also used to cool the drill bit during drilling process and flush the drill holes for removal of bone debris.

3.6.13 Closure of surgical wound

The muscle bundles were apposed with one or two simple interrupted sutures using 1/0 chromic catgut. The incised deep fascia were fused with 1/0 chromic catgut. Subcutaneous tissue was apposed in continuous pattern using 1/0 chromic catgut. Skin was united with coarse nylon in horizontal or vertical mattress pattern.

3.7 POSTOPERATIVE CARE

3.7.1 Postoperative immobilization and care of surgical site

The site of operation was covered by sterilized gauze pad dipped in povidone iodine. External coaptation with plaster of paris (POP) cast or Robert Johns bandage was done to immobilize the limb and restrict the activity level.

3.7.2 Postoperative pain management

Meloxicam[10] was administered at the dose rate of 0.2 mg/Kg body weight intramuscularly for three days to alleviate post-operative pain. In animals where non steroidal anti inflammatory drugs (NSAIDS) produced adverse effects, tramadol[11] was administered twice daily for three days at the dose rate of 2 mg/Kg body weight intravenously. Animals which showed a tendency for self mutilation of the cast were administered with haloperidol[12] intramuscularly at the dose rate of 0.2 mg/kg bodyweight. These animals were administered with Dextrose normal saline as they exhibited reduction in food and water intake.

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9. Gentamicin injection : Gentamicin 40 mg/ml. TTK health Care Ltd. Chennai (30ml vial)
10. Melonex injection : Meloxicam 5mg/ml. Intas Vet Pharma Ltd., Ahmedabad (2ml vial)
11. Supridol injection : Tramadol 50mg/ml. Neon Labs Mumbai (2ml ampoule)
12. Serenace injection : Haloperidol IP 5 mg/ml. RPG Life Sciences Ltd., Ankleswar (1ml ampoule)

3.7.3 Postoperative antibiotic therapy

Ceftriaxone[13] or ceftriaxone with tazobactam[14] was administered at the dose rate 20mg/Kg body weight twice daily for seven days preferably intravenously. When this was not practical due to owner's inconvenience, oral administration of cephalexin[15] tablets twice daily was resorted to.

3.7.4 Suture removal and removal of cast

The sutures were removed on the 8th postoperative day. The plaster cast was removed after 15 days, passive range of motion and stretching applied to the immobilized joints. Animals which needed sustained immobilization on clinical and radiographic evaluation were applied with fresh POP casts. In non complicated cases further immobilization for 15 days was done with Robert Johns bandage and restricted activity was advised for one more month.

3.8 EVALUATION OF STUDY

Clinical and radiographic evaluation of the study was carried out on the immediate postoperative day, thereafter on the 15th, 30th and 60th days.

3.8.1 Clinical evaluation

3.8.1.1 General condition and dehydration

General condition was recorded as good, fair, obese or debilitated. The dehydration status was assessed by skin tent test and general clinical examination.

3.8.1.2 Pain at the fracture site

Each animal was carefully examined for unprovoked behavioral changes like vocalization, absence of grooming and play, changes in temperament, increase in anxiety and fear, guarding or protecting the affected area and self mutilation.. The response to gentle handling of surgical site was evaluated. Clinical signs suggestive of acute pain like increased heart rate, peripheral vasoconstriction (pallor of mucous membrane) were also studied.

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13. Intacef injection : Ceftriaxone 500mg Intas Vet Pharma Ltd., Ahmedabad
14. Intacef Tazo injection : Ceftriaxone with tazobactam 562.5mg Intas Vet Pharma Ltd., Ahmedabad
15. Sporidex AF : Cephalexin 375mg tablets, Ranbaxy Laboratories Ltd., Gurgaon

3.8.1.3 Evaluation of functional limb usage

The carriage of limb on walking and standing was evaluated. Angular deformities were assessed by change in gait. The lameness was quantified in a grading system of 0 to 10. The functional limb usage was evaluated by comparing the preoperative lameness score with the postoperative values. The lameness scores exhibited on each day of observation was compared with the previous observation to evaluate functional limb usage and thereby clinical union.

3.8.1.4 Neurological examination

Test for conscious proprioception was conducted on all the patients postoperatively

3.8.2 Radiographic evaluation

Plain lateral and cranio caudal radiographs of the fractured limb were taken on the first postoperative day and thereafter on 15th, 30th and 60th days. The immediate postoperative radiographs were assessed for the 'four A's namely apposition, alignment, angulation and apparatus. The successive radiographs were assessed to the 'six A's:- Apposition, alignment, angulation, apparatus, architecture and activity.

3.8.2.1 Apposition

Percentage of contact between the fractured bone ends as evidenced from the postoperative radiograph was assessed. In the follow up radiographs it was observed whether this contact had been maintained.

3.8.2.2 Alignment and angulation

The restoration of bone as a whole was assessed. Any angular or torsional displacement relative to normal was observed. Slight cranio caudal mal alignment was considered least deleterious; however a bend in medio-lateral plane or any degree of rotation was considered undesirable. Maintenance of the alignment as compared to the previous radiograph was ascertained from the subsequent films.

3.8.2.3 Apparatus

From the immediate postoperative radiograph, the length of the implant, positioning and implant size in relation to the bone was analyzed. By this the correct usage of implant was evaluated.

In the subsequent radiographs the intactness of the implant with evidence of screw loosening, plate bending or breakage was assessed. Screw loosening was identified by a change in position or radiolucency around it.

3.8.2.4 Activity

It was an assessment of biological activity of bone in response to the fixation device. This was related to age of patient, length of time since initial stabilization and degree of functional limb usage. The type and amount of callus formation was evaluated. Any signs of infection and new bone formation were checked for. The amount of bone resorption was critically evaluated to check whether it represented normal revascularization of the bone fragment edges or indicated infection or loosening of implants. The healing was evaluated from the 15^{th} day radiograph onwards. By compression bone plating, primary bone healing was expected where in the fracture gap gradually filled by radio-opaque bone. Minimal external callus was anticipated.

3.8.2.5 Architecture

Both the architecture of the bone and surrounding soft tissue was evaluated. A decrease in size of the soft tissue shadow after compensating for the resolution of immediate postoperative swelling indicated muscle atrophy or nerve injury. Bone was evaluated for loss of density (osteopenia) or increased density associated with healing callus.

3.9 STATISTICAL ANALYSIS OF DATA

The data recorded were analyzed using paired't' test (Snedecor and Cochran, 1989).

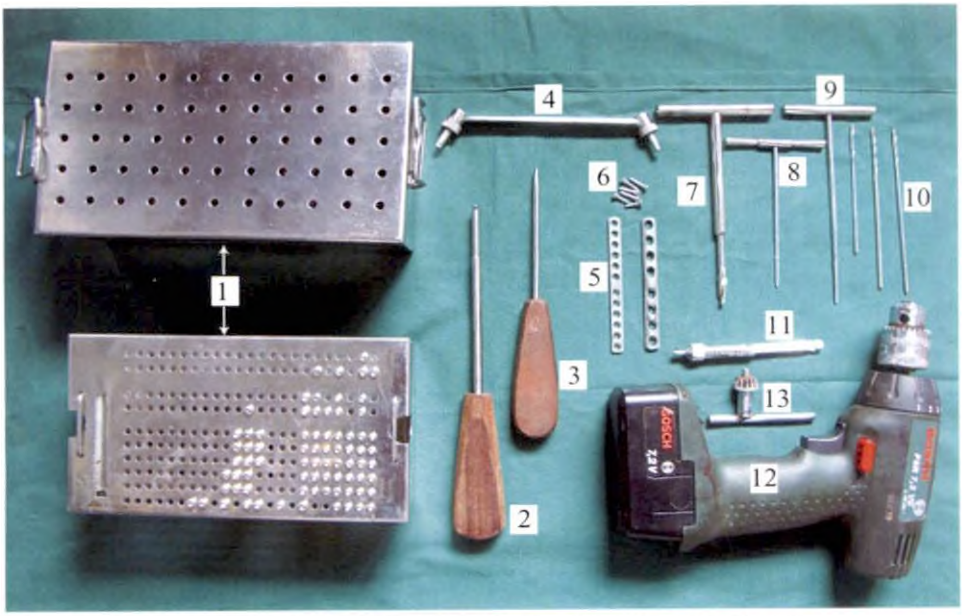


Fig. 1. Plate and Screw Instrumentation Set (AO/ASIF)

1. Screw Box & Screws
2, 3 3.5mm & 2.7mm Screw Driver
4. Neutral & Eccentric Drill Guide
5. DCP
6. Screws
7. Countersink
8, 9. Bone Taps
10. Drill Bits
11. Depth Gauge
12, 13. Power Drill & Key

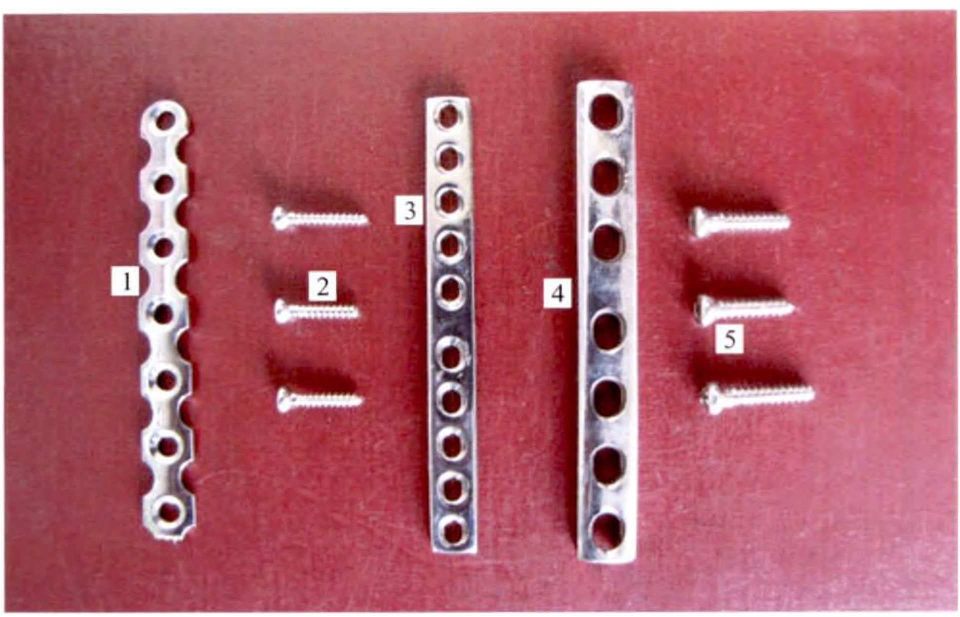


Fig. 2. Implants used

1. 2.7mm Reconstruction Plate
2. 2.7mm Screws
3. 2.7mm DCP
4. 3.5mm DCP
5. 3.5mm Screws

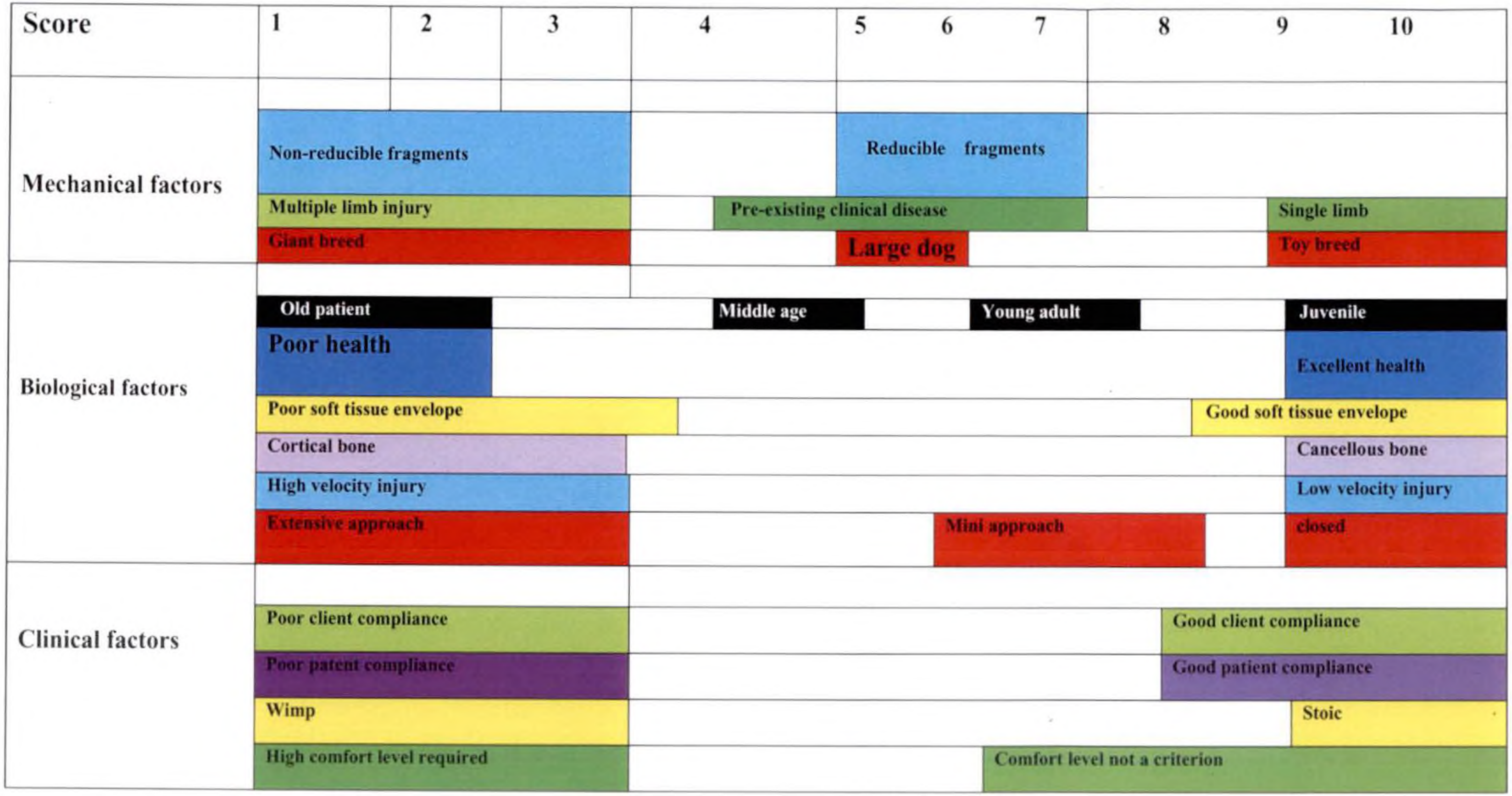
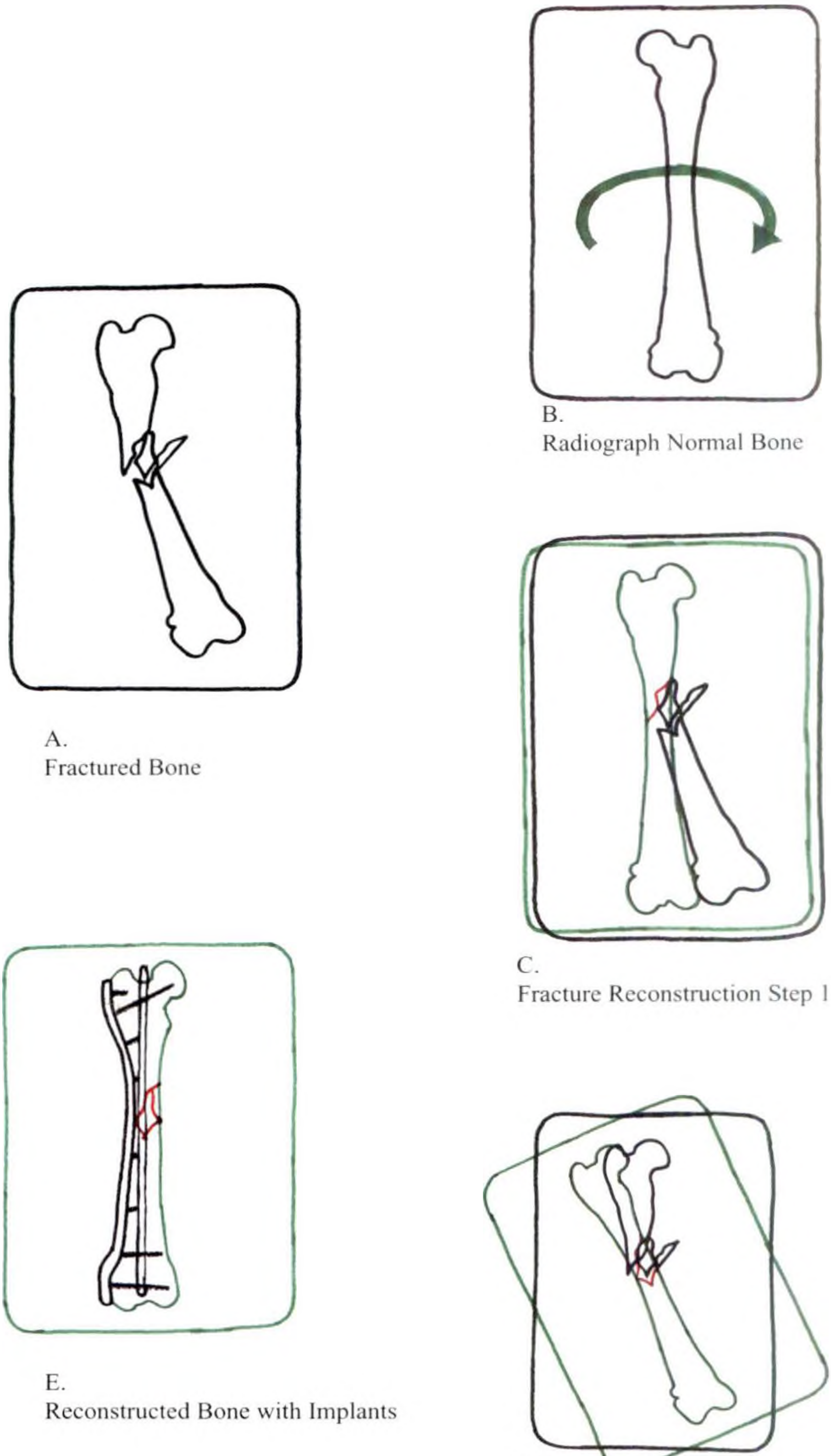


Fig. 3. Fracture Assessment Score Used for the Study



A.
Fractured Bone

B.
Radiograph Normal Bone

C.
Fracture Reconstruction Step 1

D.
Fracture Reconstruction Step 2

E.
Reconstructed Bone with Implants

Fig. 4. Preoperative Fracture Plan

Veterinary Implant Reference Chart

A guide for the selection of plates and screws with respect to animal weight and fracture location, for canine and feline patients.

DCP	Dynamic Compression Plate	RCP	Reconstruction Plate
Br. DCP	Broad Dynamic Compression Plate	MP	Mini Plate
AP	Veterinary Acetabular Plate	VCP	Veterinary Cut-to-Length Plate
Na. DCP	Narrow Dynamic Compression Plate	TPLO	Tibial Plateau Leveling Osteotomy Plate
LC-DCP	Limited Contact Dynamic Compression Plate	CRIF	Clamp Rod Internal Fixation System
LCP	Locking Compression Plate		

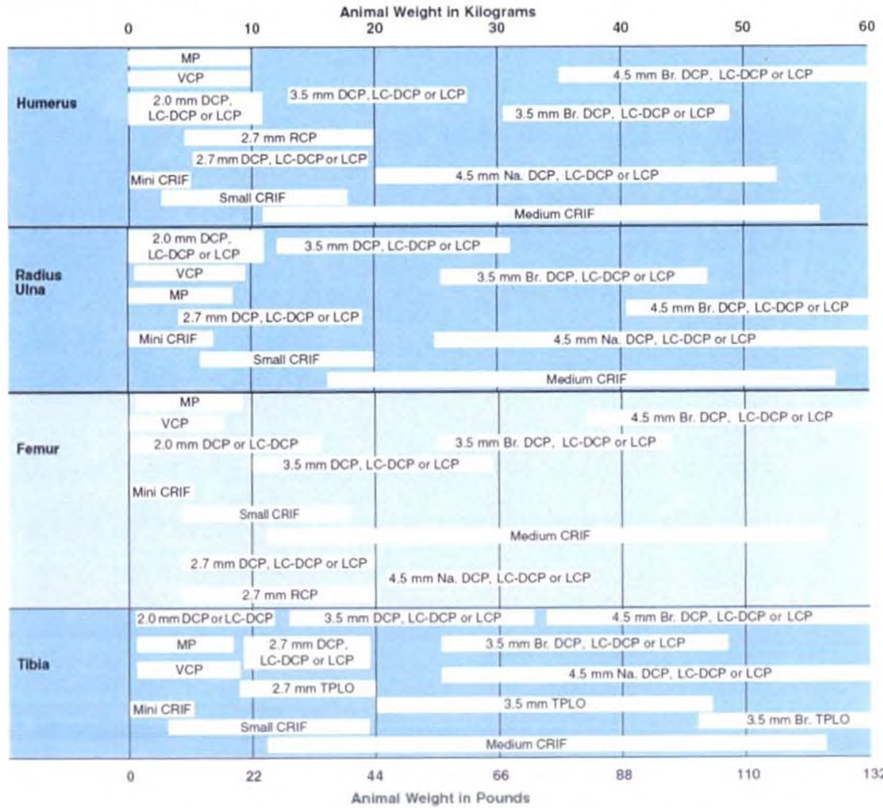


Fig. 5. Plate & Screw Chart (AO/ASIF)

Ref: Piermattei *et al* (2006).

Standard Screws, Drill Bits and Taps for Veterinary Use

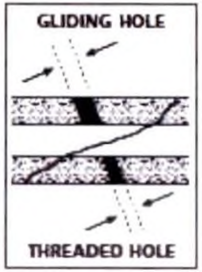
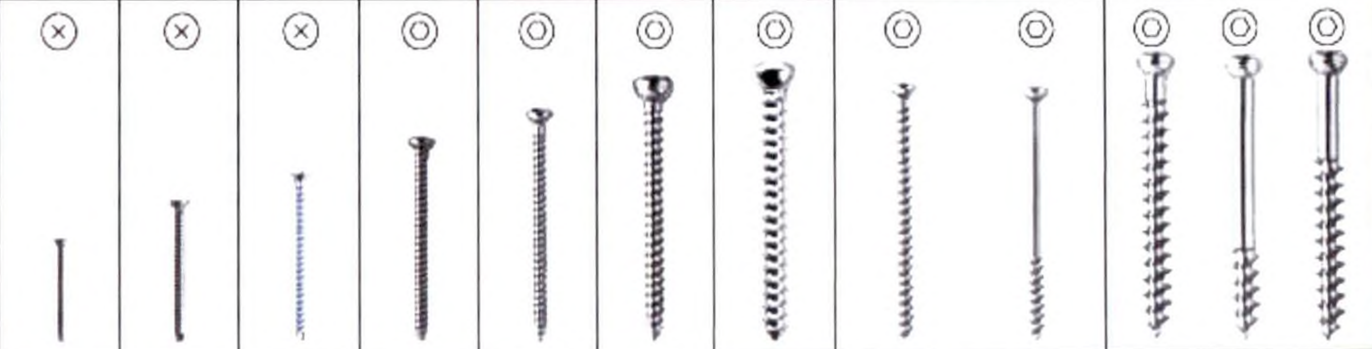
SCREW DIAMETER (mm)												
Thread Diameter	1.5	2.0	2.4	2.7	3.5	4.5	5.5	4.0		6.5		
Screw Type	Cortex							Cancellous				
								Full thread	Partial thread	Full thread	16 mm thread	32 mm thread
DRILL BIT and TAP DIAMETER (mm)												
Drill Bit for Gliding Hole	1.5	2.0	2.4	2.7	3.5	4.5	5.5	–		4.5		
												
Drill Bit for Threaded Hole	1.1	1.5	1.8	2.0	2.5	3.2	4.0	2.5		3.2		

Fig. 6. Screw & Drill Bit Chart (AO/ASIF)

Ref: Piermattei *et al* (2006).

Fig. 7. Preparation of site

Fig. 8. Preoperative traction

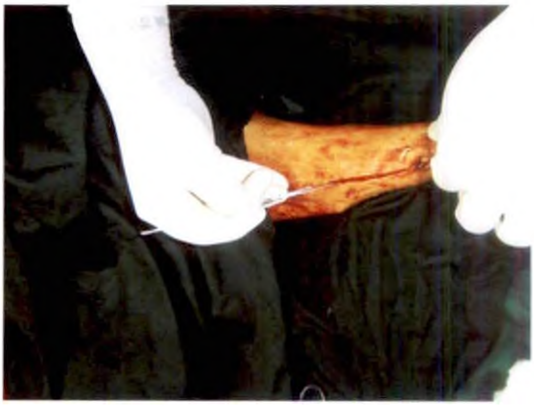
Plate 1. Approaches to bones

A. Humerus - Craniolateral

B1. Radius & Ulna - Craniomedial

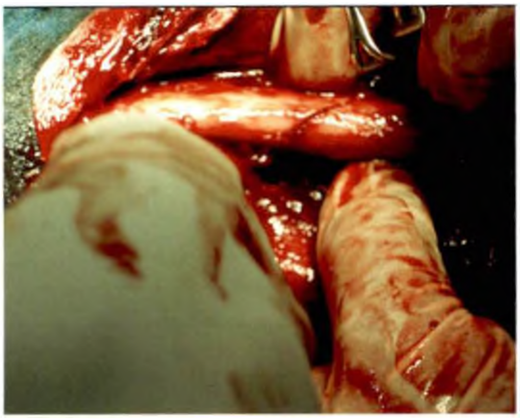
B2. Radius & Ulna - Craniolateral

C. Femur - Lateral

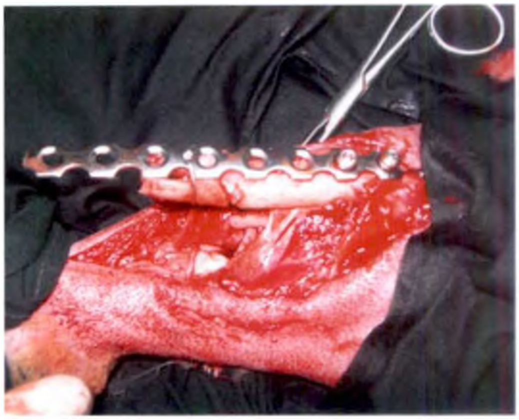


D. Tibia - Craniomedial

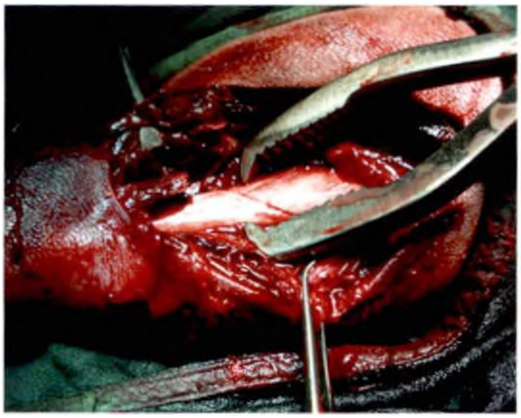
Plate 2. Fracture Reduction



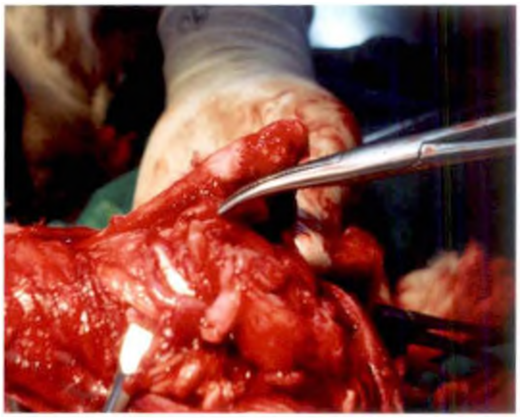
A. Short Oblique-Dog No.A1



B. Reduction with Plate and Cerclage wire
Dog No.A3



C. Reduction with Bone Holding Forceps
Dog No.A4



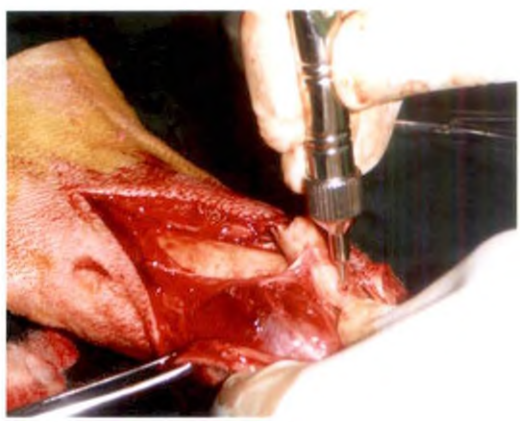
D. Fused Medullary Cavity Dog No.A5

Plate 3. Application of Neutralisation Plate-Dog No.A3

A. Exposed Fracture

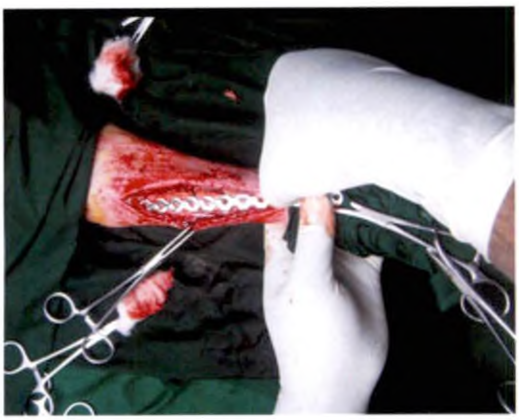
B. Cutting the Plate

C. Drilling Screw Holes

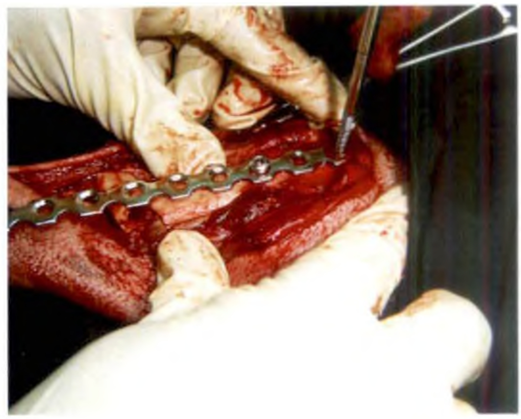


D. Measuring with Depth Gauge

Plate 3 Continued



E. Plate Application

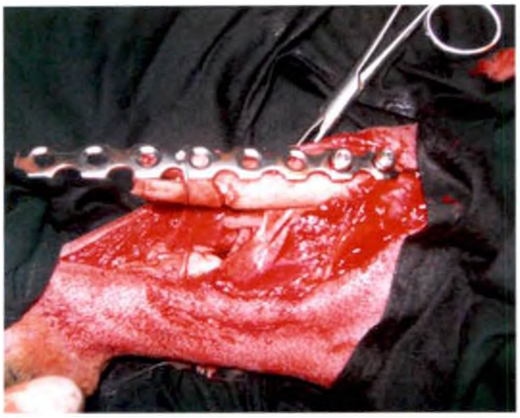


F. Tapping

G. Screw Tightening

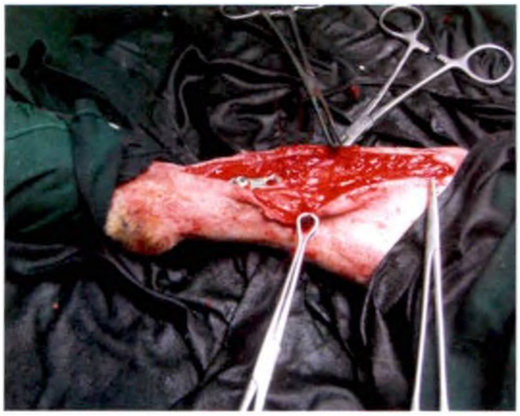
H. Cerclage Application

Plate 3 Continued



I. Fracture Reduction with Plate and Cerclage

J. Plate and Cerclage in Position



K. Apposing the Subcutaneous Tissue

L. Suturing the Skin

Results

4. RESULTS

4.1 SELECTION OF ANIMALS

Dogs presented with fractures of the diaphysis of long bones were subjected to radiography and eight dogs found suitable for bone plating were selected for the study. Plate osteosynthesis was evaluated clinically and radiographically on the first postoperative day, thereafter on the 15^{th}, 30^{th}, and 60^{th} postoperative days.

4.2 BROAD OUTLINE OF WORK

Eight clinical cases of dogs with long bone fractures confirmed by radiography were the subject for the study. Fractures studied included four tibial and fibular fractures, two radius and ulna fractures, one fracture of humerus and one femur fracture. Six fractures were stabilized with dynamic compression plates, one tibial and one humerus fractures were stabilized with reconstruction plates. Dynamic compression plates (DCP) were used in compression mode in five fractures and neutralization mode in one fracture. Both the reconstruction plates were used in neutralization mode. Following treatment, the animals were observed on the next day of operation and thereafter on the 15^{th}, 30^{th} and 60^{th} postoperative days. During these periods, the clinical condition of animals, physiological parameters, haematological parameters, radiographic evaluation and functional limb usage were observed.

4.3 SIGNALMENT AND ANAMNESIS

The signalment and exciting cause of fracture at the time of presentation were recorded (Table 1).

4.3.1 Age and sex wise distribution

Age of the study group ranged from 10 months to 10 years. Majority of the dogs were between the age group of 1- 3.5 years. The body weight ranged from 7-25.5kg. Of the animals, two were males and the rest females.

4.3.2 Breed wise distribution

Breed distribution was Non- descript (4), Labrador (1), German Shepherd Dog (1), Tibetan Terrier (1) and Labrador cross (1).

4.3.3 Fracture etiology

The exciting causes of fractures were automobile accident, fall / jump from a height and malicious injuries inflicted by man. The time lag between the trauma resulting in fracture and presentation for treatment ranged between one day and 1.5 months.

4.3.4 Anatomical location and type of fractures

The limbs affected were right forelimb in two animals, left forelimb in one animal, right hind limb in four animals and left hind limb in one animal. Bones affected were; tibia (4), radius and ulna (2), humerus (1), and femur (1). Tibial fractures represented 50% of the total fractures stabilized. This was followed by radius and ulna (25%), humerus and femur (12.5% each). Among the diaphyseal fractures studied, four were transverse (50%), three short oblique (37.5%), and one multiple (12.5%). One of the short oblique fractures was with a butterfly fragment also.

4.4 PREOPERATIVE CONSIDERATIONS

4.4.1 Evaluation of the patient

Fractures in Dog No. A3 and A6 were caused by high velocity trauma resulting from automobile accidents. Hidden injuries to core body systems were ruled out in these dogs by detailed clinical examination.

4.4.1.1 Physical examination

All the animals were active and alert preoperatively. Body condition was good in Dog Nos. A1, A4, A5 and A6 and fair in Dog Nos. A2, A3, A7 and A8. Clinical signs suggestive of dehydration were exhibited by none of the animals.

Pain and localized tenderness were manifested by Dog Nos. A1, A2, A3, A4 and A8 at the time of presentation. The fall resulting in fracture had occurred one and a half month ago in Dog No. A5 and this animal evinced moderate pain without tenderness on palpation of the fractured limb. Dog No. A6 also manifested moderate pain without tenderness. Pain was more or less absent in Dog No. A7. The fractured limb showed deformity and change in angulation in all the animals. Abnormal mobility of affected limb was observed in all the dogs.

Local swelling was observed in Dog Nos. A1, A2, A3, A4 and A8. Crepitus was palpated in all animals except Dog Nos. A5, A6, and A7. Hard irregular swelling of fractured humerus was palpated in Dog No. A7.

4.4.1.2 Orthopaedic evaluation

Locomotion, adaptation and equilibrium of ambulation were less than adequate in all the animals. All of them walked with a shortened stride. Toeing in was exhibited by Dog Nos. A1, A2 and A3 while standing (Plate 4). Dog Nos. A5 and A6 walked with a head boob.

4.4.1.2.1 Functional limb usage

Non weight bearing lameness was exhibited by all the animals. The lameness was quantified in a 0 to10 grading system and the preoperative values were summarized in table No. 6.

4.4.1.2.2 Neurological evaluation

Test for conscious proprioception was negative in all animals except Dog No. A7 which exhibited a sluggish reflex.

4.4.2 Preoperative radiographic assessment

The precise location and type of fracture determined by radiographic evaluation was recorded (Table 2).

4.4.3 Preoperative stabilization of patients

Dog No. A3 was presented with a small penetrating wound. Thorough cleansing and aseptic surgical debridement was done and surgery was undertaken in an emergency basis.

Dog No. A4 was presented with contusion and bruises at medial aspect of tibia, without loss of skin continuity. This animal exhibited severe pain at the time of presentation, so it was given meloxicam at the dose rate of 0.2 mg/kg body weight intramuscularly followed by oral route for three more days. Pyrexia was also recorded in this dog and hence it was administered with Ceftriaxone intravenously at the dose rate of 20 mg/ kg body weight followed by Cephalexin 375 mg tab twice daily for five days orally as a prophylactic measure.

Elective surgery was performed in Dog Nos. A1, A2, A4, A5, A6 and A7. In Dog No. A1, the fractured limb was temporarily immobilized with a POP cast. Robert John's bandage was used for temporary immobilization in rest of the dogs. Dog No. A8 was presented with transverse fracture of femur with a tendency for communication to outside and hence emergency reduction and fixation was done.

4.5 DECISION MAKING AND IMPLANT SELECTION

4.5.1 Fracture assessment score

The fracture assessment score for each animal based on clinical, mechanical and biological factors was deduced and summarized in table No.3. Compression plating was selected for Dog Nos. A1, A2, A5, A6 and A8 and neutralization plating for A3, A4 and A7 based on the fracture assessment score.

4.5.2 Preoperative fracture plan

The preoperative fracture plan prepared from radiographs could be used as an effective tool in deciding the implants in Dog Nos. A3, A6 and A7. In these dogs the contouring of plates was also done utilizing the radiograph of contra lateral limb as a template. The selection of implant size was further confirmed by consulting the veterinary implant reference chart (AO/ASIF). The type of implants used in each case was recorded (Table 4).

4.5.2.1 Screws

Non self tapping cortical screws of 2.7mm thread diameter were satisfactorily used in Dog Nos. A1, A2, A3, A5, A6 and A7 as plate screws. The screws used in Dog No. A4 were of thread diameter 3.5mm since the increased bodyweight of this animal necessitated the use of a bigger plate. In Dog No. A8, 2.7mm screws were initially employed, but due to stripping of screw holes few of them were to be replaced with 3.5mm screws.

4.5.2.2 Plates

Adequate compression of fractured bones could be achieved by the use of 2.7mm DCPs in Dog Nos. A1, A2, A5, A6 and A8. Reconstruction plates (2.7mm) were used as neutralization plates in Dog Nos. A3 and A7. Satisfactory static compression was achieved in Dog No. A4 by the use of a 3.5mm DCP as neutralization plate.

4.6 EVALUATION OF THE TECHNIQUE

4.6.1 Anaesthesia

Uniform anaesthetic protocol was followed in all animals except in Dog No. A6. The premedication with atropine sulphate at the dose rate of 0.045mg/kg body weight intramuscularly followed by xylazine at the rate of 1mg/ kg body weight provided satisfactory sedation. Administration of ketamine at the rate of 10mg/kg body weight intramuscularly after 15 minutes resulted in smooth induction of general anaesthesia. Satisfactory plane of anaesthesia could be maintained throughout the procedure by infusion of 1:1 mixture of xylazine and ketamine. Good muscle relaxation during surgery could be achieved by the intravenous administration of diazepam at the rate of 0.2 mg/kg body weight. The Inhalation anaesthesia with isoflurane was smooth and recovery was uneventful in Dog No. A6. In this dog, premedication with xylazine and induction with propofol as an intravenous bolus injection resulted in an anaesthetic plane suitable for endotracheal intubation.

4.6.2 Surgical site preparation

The surgical site preparation with clipping of hairs and scrubbing were done after administration of premedication for anaesthesia and by this, chances of postoperative surgical site infection could be minimized in all cases except Dog No. A4. Suspending the limb from an intravenous fluid stand provided 360^0 exposure of medial and lateral sides for effective clipping and scrubbing.

4.6.3 Preoperative traction

The hanging limb technique helped to use the animal's own weight to apply traction against gravity and aided in fatiguing the spastically contracted muscles.

4.6.4 Surgical approach

Uniform surgical approach was employed to reach tibia in Dog Nos. A1, A2, A3 and A4. Controlling the animal in right lateral recumbency and putting a cranio-medial incision provided adequate exposure of the bone in Dog Nos. A1, A2 and A3. Dog No. A4 was placed on left lateral recumbency as its left tibia was fractured. Radius was approached by putting a cranio-lateral incision in Dog No. A5. In Dog No. A6, a 10 hole DCP was used to stabilize the fracture and in order to allow placement of more screws per segment, a medial approach was selected in which medial epicondyle of humerus and styloid process of radius formed the land marks of the incision. In Dog No. A7, controlling the animal on right lateral recumbency and putting the incision cranio-laterally provided satisfactory exposure of the fractured humerus. Sufficient exposure of femur in Dog No. A8 was obtained by placing the animal in left lateral recumbency and selecting a lateral approach.

4.6.5 Fracture reduction

Satisfactory reduction of fracture fragments could be achieved in Dog No. A1 by using a scalpel handle as a lever to lift the fragment ends. After lifting, the fragments could be satisfactorily replaced in normal position by application of slow downward pressure (Plate 2-A).

Holding the fragments by two bone holding forceps and gradual application of distraction of the fragments aided satisfactory reduction in Dog No. A2.

The plate was first secured to the proximal fragment before reduction in Dog No. A3. The loose fragment was attached to the plate using a cerclage wire (Plate 2-B). The two piece fracture thus created was aligned to the distal fragment.

Fracture reduction in Dog No. A4 was achieved by applying a bone holding forceps at an angle to the fracture line and by gentle manipulation the fragments were aligned (Plate 2-C). The contoured plate was applied over the surface and held in position by the reduction forceps. In this case there was a butterfly fragment which was attached to the plate with a cerclage wire.

Fracture in Dog No. A5 was progressing to non union with fusion of medullary cavity at fracture margins (Plate 2-D). It required extensive debridement and freshening of fracture margins before final reduction. The reduction was also difficult and achieved by securing plate to the distal fragment and then aligning it to the proximal segment.

Dog No. A6 also needed freshening of the fracture margins since the trauma resulting in fracture occurred 22 days ago. Here also reduction was achieved with the aid of contoured plate which was first secured to the distal fragment.

Fracture of humeral shaft occurred in Dog No. A7 one month back and it was progressing to a malunion. There was extensive proliferation of fibrous callus throughout the diaphysis which required massive debridement and freshening of fracture margins before reduction. The reduction was achieved by elevation of fragments and manipulation with a pointed reduction forceps.

The fractured femur of Dog No. A8 was reduced by levering with a Hohman's retractor and application of gentle downward pressure. The reduction was maintained with a pointed reduction forceps.

4.6.6 Contouring of plates

The plates were contoured at the time of surgery in Dog Nos. A1, A2, A5, and A8. The reconstruction plate used in Dog No. A3 was precontoured using the radiograph of contralateral tibia as a template. The 10 hole's DCP used for Dog No. A6 was precontoured. Precontoured reconstruction plate was used for Dog No. A7. The contouring could satisfactorily be achieved by judicious use of two bending irons.

4.6.7 Prestressing of the plates

Prestressing the plates to leave a one to two millimeter gap at the fracture line ensured adequate compression of the transcortex margins in Dog Nos. A1, A2, A5 and A6. Prestressing was avoided in Dog Nos. A3 and A4 due to comminution. The contouring was less than adequate in Dog No. A8 as evidenced in the postoperative radiograph.

4.6.8 Application of plates

Plates were applied in dynamic compression mode in Dog Nos. A1, A2, A5, A6 and A8. Contoured DCP was applied to the cranial medial surface of the tibia in Dog Nos. A1 and A2 as this was the tension side and resulted in satisfactory compression of the fragments. Plate was applied to the cranial surface of radius in Dog No. A5, but the post reduction alignment of fragments was only fair. In Dog No. A6, plate was applied to the craniomedial side of radius. This enabled the use of more screws in the distal fragment and ensured good purchase of screws. The post reduction alignment was also excellent.

Compression plate was placed on the lateral surface of femur in Dog No. A8 since it was the tension band side.

In Dog Nos. A3 and A4, plates were applied on the cranial medial side of fractured tibia as neutralization plates. Reconstruction plate was applied to the cranial surface of humerus in Dog No. A7 and provided good stability to the fixation.

4.6.9 Plate fixation

4.6.9.1 Dynamic compression plating

Screw holes for Dog Nos. A1, A2, A5, A6 and A7 were drilled with a two millimeter drill bit since 2.7 mm. DCP was used in these animals in dynamic compression mode. The number of screws used per fragment was summarized in table No: 4. Dynamic compression could be ensured by drilling the first screw hole in the distal fragment using the eccentric drill guide and prestressing the plate so that a distance of 1-2mm remained above the fracture line when the plate was applied over the bone. Low speed high torque Bosch power drill was effective in reducing wobble and did not generate much heat during the drilling process. Oblique fracture lines in Dog No. A1 caused some difficulty in drilling the first screw hole in the proximal fragment. Screw placement for Dog No. A8 caused difficulties. Four numbers of 3.5mm screws were to be used, two in each fragment since stripping of screw holes occurred while tapping with a 2.7mm tap. This necessitated use of an over sized tap (3.5mm) and screws.

4.6.9.2 Neutralization plating

DCP was used as a neutralization plate in Dog No. A4. Reconstruction plates were used in Dog Nos. A3 and A7 and they were also applied as neutralization plates. Use of a lag screw to secure the loose fragment in Dog No. A3 failed as the transcortex began to split. Interfragmentary compression could be effectively achieved in this dog by the application of a cerclage wire. Plate was placed on the tension side of bone to protect the weak cerclage wire from disruptive fracture forces (Plate 3 D). In Dog No. A4 also cerclage wire was used to fix the butterfly fragment and to provide interfragmentary compression. In this animal, a 7 holed 3.5mm plate was used effectively to neutralize the disruptive fracture forces. In Dog No. A7, the oval holes of reconstruction plate provided some axial compression also.

All the screw holes were drilled using the neutral drill guide in Dog Nos. A3, A4 and A7. In these cases screws were not used to generate compression between fragments. Screws used in Dog No. A4 were 3.5 mm. and the drill bit used was 2.5mm.

4.6.10 Intraoperative lavage of surgical site

Constant flushing of drill holes and drill bits with gentamicin mixed normal saline effectively reduced heat generated during drilling process and helped to remove bone debris.

4.6.11 Closure of surgical wound

The suture techniques and materials used for the closure of the separated muscle bundles, dissected fascia, subcutaneous tissue and skin were satisfactory and facilitated uneventful healing all dogs except Dog No. A4. In this animal wound dehiscence and reaction to surgical gut was observed.

4.7 POSTOPERATIVE MANAGEMENT

4.7.1 Postoperative immobilization

After fixation with plates, the fractured limb in all dogs except Dog No. A2 were immobilized with plaster of paris (POP) casts. Robert Johns bandage was used in Dog No. A2. The postoperative casts/dressings were well accepted by Dog Nos. A2, A3, A5, and A6. Dog No. A7 developed swelling and oedema of paw distal to the POP cast. This subsided in two days once the cast was cut at the distal borders and magnesium sulphate- glycerin paste applied to the swollen area. The external immobilization helped to protect the implants from fatigue failure and restricted the activity level also. Implant fatigue failure subsequent to self mutilation of the cast was observed in Dog No. A8.

4.7.2 Postoperative pain control

Immediate postoperative administration of meloxicam at the dose rate of 0.2mg/kg body weight intramuscularly provided immediate pain relief in all the dogs. In Dog Nos. A1, A2 and A5, this was followed by oral route for two more days and was effective in managing postoperative pain. Dog No. A3 was hypersensitive to non steroidal anti inflammatory drugs (NSAIDS). Hence it was administered with tramadol at the dose rate of 2mg/kg body weight intravenously twice daily for 3 days which was also effective in providing postoperative analgesia. Dog Nos. A7 and A8 were given haloperidol once daily at the dose rate of 0.2 mg/kg body weight intramuscularly for three days which not only reduced pain but prevented self mutilation of cast and skin sutures. These animals exhibited reduction in food and water intake which was corrected by intravenous administration of dextrose normal saline at the rate of 15ml/ kg body weight.

4.7.3 Postoperative antibiotic therapy

Dog No. A1 was administered with ceftriaxone intravenously at the dose rate of 20mg/ kg body weight which was followed by Cephalexin 325 mg. oral tablet twice daily for seven days. Dog No. A2 was given ceftriaxone 250mg twice daily for seven days intramuscularly. The intravenous administration of ceftriaxone was followed by oral Cephalexin tablets (325mg) in Dog No. A4. The same antibiotic regimen was followed in Dog No. A5 also due to owner's inconvenience to bring the animal regularly for follow up antibiotic therapy. Dog Nos. A3, A6, A7 and A8 were administered with ceftriaxone tazobactam combination at the dose rate of 20mg/kg body weight intravenously twice daily for seven days. The postoperative antibiotic regimen was quite satisfactory except in Dog No. A4 where suture dehiscence and postoperative wound infection occurred.

4.7.4 Suture removal and removal of cast

The sutures were removed on the eighth postoperative day in all dogs after removal of the cast. The suture lines were intact in all dogs and clinical signs suggestive of inflammation were exhibited only by Dog No. A4. Dog No. A6 developed a pressure sore at the elbow region on the fifteenth day which healed after removal of the POP cast and application of Robert johns bandage.

4.8 POSTOPERATIVE EVALUATION OF THE PATIENT

The dogs were evaluated clinically and radiographically on the immediate postoperative day and thereafter on the 15th, 30th and 60th days. Dog No. A4 died on the 45th postoperative day. The post mortem diagnosis was ulcerative enteritis and acute renal failure (Fig. 9 & 10).

4.8.1 Clinical evaluation

4.8.1.1 General condition and dehydration

The dogs were active and alert throughout the observation period. Body condition was good in Dog Nos. A1, A4, A5 and A6 and fair in A3, A7 and A8. No signs of dehydration were exhibited during the observation period.

4.8.1.2 Pain at the fracture site

Behavioral changes associated with pain like vocalization, guarding the injured area and limb disuse were exhibited by Dog No. A3 postoperatively which could be managed by administration of tramadol. Dog No. A4 exhibited symptoms like reduction in appetite, vocalization and biting at the surgical site following wound dehiscence. The pain on surgical site was absent from 15th day onwards in Dog Nos. A2, A5, A6, A7. Severe pain at fracture site and guarding of the injured limb were observed in Dog No. A8 from ninth postoperative day onwards.

4.8.1.3 Postoperative evaluation of the functional limb usage

The comparative lameness scores exhibited by the dogs following plate fixation were summarized in table No.5.

Among the four tibial fractures stabilized, Dog No. A1 started to show partial weight bearing on the fifteenth postoperative day following fracture repair (lameness score of five). Slight ground contact was manifested by this animal on the eighth postoperative day when brought for suture removal. The lameness score remained same as that of preoperative value. The score progressed to three by the thirtieth postoperative day. Dog No. A2 showed partial weight bearing on the second postoperative day itself (lameness score of six).

Dog No. A3 with multiple fracture and soft tissue injury showed slight ground contact on the 8^{th} day onwards and progressed to a score of five on the 15^{th} day. Near to normal limb usage was observed on the 30^{th} day (Plate 5).

Dog No. A4 developed wound dehiscence and secondary sepsis and accompanied reduction in functional limb usage. Partial weight bearing was observed on the 15^{th} day with a lameness score of five which remained so up to the thirtieth day. On telephonic conversation owner had reported a near to normal weight bearing on the 40^{th} day. The observation could not be continued following sudden death of this animal on the 45^{th} day of plate fixation.

Dog No. A5 with non union fracture of radius ulna showed moderate lameness on the fifteenth day followed by mild lameness on the 30^{th} day. Sound limb usage was manifested on the 60^{th} day.

Partial weight bearing was exhibited on the second postoperative day itself by Dog No. A6. Mild lameness was exhibited on the 15^{th} day. The lameness score progressed to one by the 30^{th} day (Plate 6).

Dog No. A7 with old fracture of humerus showed a progress in lameness score from seven to five on the second postoperative day itself. The functional limb usage steadily progressed to score of two by the fifteenth day and almost sound usage with score of one was observed on the 30^{th} day.

Dog No. A8 showed partial weight bearing from the second postoperative day itself. But following self mutilation of cast, sudden lameness developed in this animal from the 9^{th} day with valgus displacement of femur.

4.8.1.4 Neurological examination

Test for conscious proprioception was conducted on all the patients postoperatively. The reflex was normal from the second postoperative day in Dog Nos. A1, A2, A6, A7 and A8. Reflex was sluggish during the 1^{st} postoperative week in Dog Nos. A3 and A5 and improved by the 15^{th} day. Dog No. A4 exhibited a sluggish reflex up to the 15^{th} day and showed almost normal reflex by the 30^{th} day onwards.

4.8.2 Physiological parameters

The physiological parameters were recorded preoperatively and thereafter on the 1^{st}, 15^{th}, 30^{th} and 60^{th} postoperative days and the mean ± standard error (SE) values were summarized in table No: 6

4.8.2.1 Respiratory rate

Respiratory rate (per min.) observed was 30.25 ± 1.39 on the day of presentation and was within the normal range. The respiratory rates recorded were 32.13 ± 1.44, 32.75 ± 1.81, 32.50 ± 2.16 and 30.40 ± 0.75 on the 1st, 15^{th}, 30th and 60^{th} postoperative days respectively. These variations were found to be insignificant and remained within the normal range

4.8.2.2 Pulse rate

Pulse rate (per minute) was 94.50 ± 2.35 on the day of presentation and was within the normal range. The pulse rates recorded were 91.50 ± 0.73, 94.13 ± 1.34, 95.25 ± 1.64 and 95.20 ± 1.50 on the 1^{st}, 15^{th}, 30^{th} and 60^{th} postoperative days respectively. The variations observed were within the normal range.

4.8.2.3 Rectal temperature

Hyperthermia was exhibited by Dog No. A4 preoperatively. The rectal temperature (^{0}C) was 39.08 ± 0.21 preoperatively and was within the normal range in all the other dogs. The temperature recorded was 38.90 ± 0.09, 38.75 ± 0.09, 38.75 ± 0.11 and 38.82 ± 0.04 on the 1^{st}, 15^{th}, 30th and 60^{th} postoperative days respectively and remained within normal range.

4.8.2.4 Colour of mucous membrane

The mucous membrane was congested in Dog No. A1 preoperatively and remained so on the 1^{st} postoperative day. The colour became pale roseate by the 15^{th} postoperative day. In all other animals, mucous membrane was pale roseate on the day of presentation and remained so throughout the observation period.

4.8.3 Haematological Evaluation

Haemoglobin concentration (g %) was 12.65 ± 0.49 preoperatively. The values were 12.55 ± 0.45, 12.83 ± 0.44, 12.80 ± 0.50 and 12.76 ± 0.85, on the 1st, 15^{th}, 30th and 60^{th} postoperative days respectively. There was no significant variation in haemoglobin concentration throughout the observation period.

The preoperative value of volume of packed red cells (VPRC) (%) was 35.03 ± 1.58. It was 34.58 ± 1.50, 36.30 ±1.24, 36.35 ±1.62 and 36.82 ± 2.69 on the first postoperative, 15th, 30th and 60th days respectively. There was no significant variation in VPRC values between the preoperative and postoperative figures.

The erythrocyte sedimentation rate (ESR) (mm/hr) was 2.00 ± 0.60 preoperatively. The postoperative values were 3.25 ± 1.69, 1.50 ± 0.27, 1.63 ± 0.18 and 1.33 ± 0.33 during the first postoperative, 15th, 30th and 60th days respectively. The variations were insignificant throughout the observation period.

The total leukocyte count (TLC) (x 10^3 /mm^3) was 13.01 ± 1.05 preoperatively. It was 16.03 ± 1.55, 14.91 ± 1.30, 13.41 ± 1, 13 and 12.54 ± 1.58 respectively during the first postoperative, 15th, 30th, and 60th days. A significant increase was noticed on the 1st postoperative day which returned to normal values by the 30th postoperative day.

The mean neutrophil count (%) was 75.75 ± 2.27 preoperatively. The postoperative values were 79.25 ± 2.09, 77.25 ± 2.09, 76.38 ± 2.11 and 71.60 ± 4.24 respectively on the 1st, 15th, 30th and 60th days. The variations were insignificant.

The preoperative lymphocyte count was 20.88% ± 1.90. It was 18 ± 2.04, 19.13 ± 1.92, 20.25 ± 1.85 and 22.20 ± 3.23 on the 1st, 15th, 30th and 60th postoperative days respectively. No significant variation was observed throughout the observation period.

The mean eosinophilic count was 2.88 ± 1.13 preoperatively. The postoperative values were 2.38 ± 0.38, 3.00 ± 0.53, 2.50 ± 0.57 and 4.80 ±1.62 on the 1st, 15th, 30th and 60th postoperative days respectively. There was no significant variation throughout the observation period.

The mean monocytic count (%) was 0.63 ± 0.32 preoperatively. It was 0.38 ± 0.26, 0.63 ± 0.32, 0.88 ± 0.35 and 1.40 ± 0.40 during the 1st, 15th, 30th, and 60th postoperative days respectively. The variations were found to be insignificant.

The haematological parameters evaluated during the observation period were summarized in table No: 7.

4.8.4 Serum biochemical evaluation

The serum alkaline phosphatase (ALP), serum calcium and phosphorus were estimated preoperatively, on the 1^{st} postoperative day and thereafter on the 15^{th}, 30^{th} and 60^{th} days. The vales were plotted in table No: 7.

The preoperative value of serum alkaline phosphatase was 127.13 ± 13.96. The postoperative values were 209.25 ± 27.82, 196.63 ± 29.81, 193.13 ± 31.07 and 160 ± 16.90 respectively on the 1^{st}, 15^{th}, 30^{th} and 60^{th} postoperative days. The ALP value showed a significant increase on the 1^{st} postoperative day, remained higher during the 15^{th} and 30^{th} postoperative days (Fig. 11).

The mean serum calcium concentration was 9.46 ± 0.23 preoperatively. It was 9.37 ± 0.27, 9.26 ± 0.25, 9.35 ± 0.23 and 9.32 ± 0.28 during the 1^{st} postoperative day and thereafter on the 15^{th}, 30^{th} and 60^{th} days respectively. No significant changes were observed during the postoperative period.

The preoperative value for serum phosphorus was 4.99± 0.90. It was 4.08 ± 0.38, 5.31 ± 0.46, 4.71 ± 0.30 and 3.64 ± 0.29 on the 1^{st} postoperative day and thereafter on the 15^{th}, 30^{th} and 60^{th} days respectively. No significant changes were observed during the period of observation.

4.8.5 Radiographic evaluation

The preoperative radiograph was used to classify and determine the exact location of the fracture. Direction of fracture line, the number of fragments and level of bone affected were also detected. Postoperative radiograph was evaluated for apposition, alignment and angulation and apparatus ('fourA's). The follow-up radiographs were evaluated for all the above parameters plus activity and architecture. The data were summarized table No. 8.

4.8.5.1 Preoperative day

Based on radiographic appearance, the fractures could be described preoperatively as follows: simple complete short oblique fracture of mid shaft of right tibia (Dog No. A1), simple complete transverse fracture of mid shaft of right tibia and fibula with serrated ends (Dog No. A2), multiple fracture of midshaft right tibia and fibula (Dog No. A3), short oblique fracture with butterfly fragment at the junction between proximal and middle third of left tibia and fibula (A4), simple complete short oblique fracture at the junction between distal and middle third of right radius and ulna- 1½ month old (Dog No. A5), simple complete transverse fracture of right radius and ulna at the junction between distal and middle third (Dog No. A6), simple old fracture of mid shaft of right humerus advancing to malunion - 22 days old (Dog No. A7), simple complete transverse fracture mid shaft of right femur (Dog No. A8).

4.8.5.2 Apposition

4.8.5.2.1First postoperative day

The postoperative contact between fracture fragments was good in Dog Nos. A1, A2, A3 (plate 8-B) and A7, excellent in Dog No. A6 and fair in Dog Nos. A5 and A8. In Dog No. A1, a butterfly fragment was seen formed between the major fragments, but it was seen fixed by the screw. In Dog No. A2 and A4, a gap of about 2mm was observed between the fracture fragments.

4.8.5.2.2 Fifteenth postoperative day

Apposition between the fragments remained fair in Dog Nos. A1 and A5 while good apposition was seen in Dog Nos. A2, A3, A4, and A7. In Dog No. A6, the excellent apposition was maintained, but it became poor in Dog No. A8. In Dog No. A1, slight increase in the gap between fracture fragments was observed with medial displacement of butterfly fragment. In Dog No. A8, plate bending, screw loosening and subsequent loss of contact between the fragments was observed (Plate 10-B).

4.8.5.2.3 Thirtieth postoperative day

The apposition remained the same as that of previous radiograph in Dog Nos. A1, A2, A3, A4, A5, A6 and A7. The plate bending and screw pullout was so severe in Dog No. A8 that the contact between the fragments was almost completely lost (Plate 10-C).

4.8.5.2.4 Sixtieth postoperative day

Radiographic observations of Dog Nos. A1 and A2 could not be done on the 60th postoperative day as they were not brought by the owners. Instead, these animals were presented on the 270th and 150th days respectively. Among the other dogs, good apposition was maintained in A3, A4, and A7. Fair apposition was maintained in Dog No. A5 while the contact between fragments remained excellent in Dog No. A6.

4.8.5.2.5 Ninetieth postoperative day

The bony continuity of radius had been reestablished in Dog No. A6 by the 90^{th} postoperative day. Good apposition was maintained in Dog No. A7.

4.8.5.2.6 One hundred and twentieth postoperative day

Re-alignment of fragments was complete in Dog No. A6 (Plate 7-G).

4.8.5.2.7 One Hundred and fiftieth postoperative day

In Dog No. A2, the fracture margins were still faintly visible with a mild gap between the fragments on the 150^{th} postoperative day.

4.8.5.2.8 Two hundred and seventieth postoperative day

Bony continuity had been re-established in Dog No. A1 as evidenced by continuation of medullary cavity and cortical union.

4.8.5.3 Alignment and angulation

4.8.5.3.1 First post operative day

Good alignment with less than 10^0 angulations in any axis was observed postoperatively in Dog Nos. A1, A2, A3, A4 and A7 (Plate 9-B). Excellent alignment (mal-alignment in any plane less than 5^0) was seen in Dog No. A6 (Plate 7-B). The alignment of fragments was fair in Dog Nos. A5 and A8 (mal-alignment in any plane less than 30^0). Slight craniocaudal mal-alignment of radius was observed in Dog No. A5 while Dog No. A8 exhibited mild mediolateral mal-alignment.

4.8.5.3.2 Fifteenth postoperative day

Alignment was fair in Dog No. A1 with a less than 30^0 angulation in craniocaudal axis. Good alignment as that of previous radiograph was maintained by Dog Nos. A2, A3, and A4. Dog Nos. A5 and A6 maintained the same alignment as that of previous radiograph. In Dog No. A7, mild craniocaudal angulation of the fragments was observed; however good alignment was maintained in this animal also. The alignment became poor in Dog No. A8 due to the increased mediolateral angulation caused by the bend plate and loosened screws.

4.8.5.3.3 Thirtieth postoperative day

Alignment of main fragments was fair in Dog No. A1, but the butterfly fragment had migrated caudally. The good alignment was maintained in Dog Nos; A2, A3, A4, and A7. The alignment remained unchanged in Dog Nos. A5 and A6 also; however in Dog No. A8 valgus mal-alignment was evident.

4.8.5.3.4 Sixtieth postoperative day

Alignment and angulation were unchanged as compared to the previous radiographs in Dog No. A3, A4, A5, A6 and A7.

4.8.5.3.5 Ninetieth postoperative day

Excellent alignment as that of previous radiograph was seen maintained in Dog No. A6. The alignment was unchanged in Dog No. A7 also.

4.8.5.3.6 One hundred and twentieth postoperative day

The fractured bones had regained their normal anatomical contours in Dog Nos. A6 and A7 as per the radiographs.

4.8.5.3.7 One Hundred and fiftieth postoperative day

Good alignment had been maintained in Dog No. A2 as per the radiograph.

4.8.5.3.8 Two hundred and seventieth postoperative day

Fractured bone had regained the normal anatomical straightness in Dog No. A1 as observed in the radiograph.

4.8.5.4 Apparatus

4.8.5.4.1 1st postoperative day

The length and size of implants were appropriate for the immobilized bones in all dogs. The stability of fixation was adequate in all dogs except Dog No. A8. Screw purchase was less than adequate in the transcortex of distal fragment in Dog No. A-1 (about 80% screw purchase was only observed radiographically). In Dog No. A4, the last screw of distal fragment hardly gained full purchase in transcortex. The screw head of most distal screw was not properly seated in the plate hole in Dog No. A7. In Dog No. A8, reduced purchase of screws was observed in the distal fragment resulting in inadequate contact between plate and bone. Absolute stability of fixation could not be confirmed radiographically in this dog.

4.8.5.4.2 Fifteenth postoperative day

The implants were intact and the fixation devices were functioning as intended to maintain stability of the fracture in most of the dogs. In Dog No. A2, mild displacement of plate (about 1.5mm) was observed; however overall stability of the device was satisfactory in this animal. The cerclage wire used to produce interfragmentary compression was seen broken in the radiograph of Dog No. A4 and as a result slight migration of two proximal screws from the distal fragment was observed. Mild bending of plate was observed in Dog No. A7. In Dog No. A8, plate bending and screw loosening were observed radiographically.

4.8.5.4.3 Thirtieth postoperative day

Screw loosening was observed in Dog Nos. A1 and A2. Loosening of 3rd screw of proximal fragment was observed in Dog No. A1 while second screw on the proximal fragment was loosened in Dog No. A2. In Dog No. A4, reduction in plate-bone contact at the distal fragment by about two mm with migration of two distal screws was evident on the radiograph. The broken cerclage wire was seen retained in position in this animal. The implant was not at all providing stability for the fixation and plate was more bent compared to last radiograph in Dog No. A8. Almost complete pullout of screws from the distal fragment was also observed in this dog. In Dog Nos. A3, A5 and A6, the implants were stable and were maintaining rigidity of fixation. In Dog No. A7, no further bending of plate was noticed and the implants were seen stabilized by proliferating callus.

4.8.5.4.4 Sixtieth postoperative day

Fixation device was functioning as intended and maintaining stability at the fracture site in Dog Nos. A3, A5, A6 and A7. The screws were intact and plates were maintaining adequate contact with bony cortex.

4.8.5.4.5 Ninetieth postoperative day

All screws were intact and plate was maintaining adequate contact with the cortex as in the previous radiographs in Dog Nos. A6 and A7.

4.8.5.4.6 One hundred and twentieth postoperative day

The implant was intact in Dog No. A6 as seen in the radiograph.

4.8.5.4.7 One Hundred and fiftieth postoperative day

Radiograph revealed intact implant without further loosening of screws in Dog No. A2. Contact between plate and bone was unchanged as compared to the last radiograph.

4.8.5.4.8 Two hundred and seventieth postoperative day

The implant was found to be stable without any radiolucency around the screws in Dog No. A1. Loosened screw observed in the previous radiograph was seen stabilized by the callus. .

4.8.5.5 Activity

4.8.5.5.1 Fifteenth postoperative day

Fracture margin was visible in Dog No. A1 with hardly any callus. In Dog No. A2, radio-opaque osseous tissue was seen gradually filling the fracture gap without evident periosteal callus. Fading of fracture lines with widening of the fracture gap and moderate quantity of periosteal callus was observed in Dog No. A3 (Plate 8-C). Radiograph of Dog No. A4 revealed indistinct fracture margins. In Dog No. A5, fracture line was less distinct with evidence of primary healing at areas of direct contact between the fragments. Moderate quantity of bridging callus was observed in the ulna.

Gradual dissolution of fracture margins was observed in the radiograph of Dog No. A6 with radio opaque bone bridging the fracture gap (Plate3-C). Healing of fractured ulna was observed by endosteal callus formation.
Radiograph of Dog No. A7 revealed widening of the fracture gap with indistinct margins (Plate 9-C). Periosteal callus proliferation was observed throughout the length of far cortex.

In Dog No. A8, the fracture line was visible through indistinct. Mild proliferation of endosteal callus was observed in this dog.

4.8.5.5.2 Thirtieth postoperative day

In Dog No. A1, periosteal callus was seen forming from the proximal fragment. The type of healing observed was secondary with callus proliferation.

Radiograph of Dog No. A2 revealed hardly any periosteal callus. Small bridging callus was observed in this dog between the fragments. Fracture margins were only faintly visible.

In Dog No. A3, the fracture lines were only faintly visible. Moderate quantities of endosteal and periosteal callus were seen gradually filling the fracture gap (Plate 8-D). The fibula showed multiple fragments and angulation in this dog.

Mild proliferation of periosteal callus was observed around the proximal screw on the ciscortex in Dog No. A4. Moderate periosteal reaction was observed at transcortex region around the upper margin of the butterfly fragment. Dissolution of distal border of the fracture fragment was also seen with minimal periosteal reaction.

Radiograph of Dog No. A5 revealed gradual dissolution of fracture lines in the plated radius without callus formation. Callus bridging of fractured end of ulna was observed in this dog.

Union of transcortex margins with radio opaque bone was observed in Dog No. A6 (Plate 7-D).

In Dog No. A7, periosteal callus proliferation was observed in the radiograph along the entire length of transcortex of the fractured bone. Callus proliferation was less on the transcortex margin immediately opposite the fracture gap (Plate 9-D). Fracture line was indistinct. Endosteal callus was bridging the fracture gap.

The fracture line was visible in Dog No. A8 with hardly any callus activity.

4.8.5.5.3 Sixtieth postoperative day

In Dog No.A3, callus bridging of fracture gap was complete (Plate 8-D).

Radiograph of Dog No. A5 revealed union of the radial fragments by direct healing. Continuity of transcortex was observed with dissolution of fracture borders. About 30% defect persisted in the ciscortex due to the mal-apposition. Ulnar fragments were bridged by callus proliferation.

In Dog No. A6, the fracture gap was almost completely disappeared. Bony continuity was re-established in the far cortex (Plate 7-E). Fracture gap was still evident between ulnar fragments and small periosteal callus was seen bridging the cortices.

In Dog No. A7, the radiograph revealed a reduction in size of the dense periosteal callus (Plate 9-E). Fracture gap was still visible in the radiograph though indistinct.

4.8.5.5.4 Ninetieth postoperative day

Radial union was almost complete in Dog No. A6 as per the radiograph. Gap between ulnar fragments was still visible (Plate 7-F).

In Dog No. A7, the medullary and cortical continuity was almost completely regained. Callus remodeling and condensation was also observed (Plate 9-F).

4.8.5.5.5 One hundred and twentieth postoperative day

In Dog No. A6, cortical and medullary integrity of radius had been re-established indicating radiographic healing (Plate 7-G).. The ulnar fragments were uniting with moderate endosteal and periosteal callus.

4.8.5.5.6 One hundred and fiftieth postoperative day

Moderate quantity of periosteal callus was observed in the radiograph of Dog No. A2 which was gradually connecting the fracture gap. A delay in healing was radiographically evident in comparison to the last radiograph.

4.8.5.5.7 Two hundred and seventieth postoperative day

The callus was observed in the stage of remodeling in Dog No. A1 and cortical integrity was almost completely restored.

4.8.5.6 Architecture:

4.8.5.6.1 Fifteenth postoperative day

Size and character of soft tissue were unaltered in all the dogs as per radiographic evidence. The bone density also remained unchanged.

4.8.5.6.2 Thirtieth postoperative day

Both the soft tissue and bone density were unchanged as that of the previous radiograph in all dogs.

4.8.5.6.3 Sixtieth postoperative day

The soft tissue shadows around the stabilized bones were similar to that of previous radiographs in Dog Nos. A3, A5, A6 and A7. The radiographic densities of the bones were also unaltered in all dogs except Dog No. A7, where an increase in the density of periosteal callus was observed.

4.8.5.6.4 Ninetieth postoperative day

The size and character of soft tissue and the bone density remained the same as that of previous radiograph in Dog No. A6. In Dog No. A7, an increase in the density of callus was observed due to condensation.

4.8.5.6.5 One hundred and twentieth postoperative day

The size and character of soft tissue and bone density remained unaltered in Dog No.A6

4.8.5.6.6 One Hundred and fiftieth postoperative day

The soft tissue and bone density remained unchanged radiographically in Dog No. A2.

4.8.5.6.7 Two hundred and seventieth postoperative day

The size and character of soft tissue was unchanged radiographically in Dog No. A1. Increased cortical density was observed along the fused fracture margins.

4.9 MANAGEMENT OF COMPLICATIONS

Postoperative complications observed were self mutilation of the cast, suture dehiscence and secondary bacterial infection, breakage of cerclage wire and plate bending and screw loosening.

4.9.1 Self mutilation of the cast

Dog No. A1 mutilated the cast even after three repeated applications. Application of Robert Johns bandage was also not successful. The sutures were removed on the eighth postoperative day and strict cage rest and leash walking advised for a month. Other complications observed were mild itching and hyperaemia at the suture site which responded to application of zinc oxide ointment.

Dog No. A7 also mutilated the cast on the 10th day which was replaced by a Robert Johns bandage. Strict cage rest and controlled leash walking led to an uneventful recovery.

Dog No. A8 removed the cast by its own on the 8th day. The very next morning the animal developed non weight bearing lameness and valgus displacement of fractured femur. Plate bending and screw loosening were observed on subsequent radiograph.

4.9.2 Suture dehiscence and secondary bacterial infection

Dog No. A4 was presented on the eighth postoperative day with lameness and behavioral alterations suggestive of pain. On removal of the cast, discharge of sanguineous exudates from the incision site was observed. Signs of bacterial sepsis with suture dehiscence were noticed. The catgut used to appose fascia and subcutaneous tissue was seen protruding out through the wound. It was removed and the wound flushed with sterile warm hypertonic saline solution. The wound was debrided and dressed with povidone iodine solution and the limb immobilized with a POP cast putting a window at the wound site. The wound dressing was repeated on alternate days. Due to paucity of muscles at the medial part of tibia, the implant was visible through the wound. Once the wound became healthy, skin and subcutaneous tissue was freed from the surrounding area and used to put few interrupted sutures.

4.9.3 Breakage of cerclage wire

The cerclage wire used to provide interfragmentary compression of the butterfly fragment in Dog No. A4 was observed broken on the 15th postoperative day radiograph. The animal was being treated for suture dehiscence and secondary sepsis. So removal of this wire was not attempted till the thirtieth postoperative day. On removal of the wire, good improvement in the condition of animal was observed and rapid wound healing observed.

4.9.4 Plate bending and screw loosening

Dog No. A8 developed severe pain of fractured limb and lameness on the ninth postoperative day following self mutilation of the POP cast. The 15th postoperative day radiograph revealed bending of the plate at the region of fracture and loosening of screws at the distal fragment. Re-application of a full limb cast and strict cage rest did not solve the problem. On the 30th postoperative day radiograph, almost complete failure of implant was observed.

4.10 PLATE REMOVAL

The plate was removed in Dog No. A6 on the fifth month since the animal exhibited pain on palpation of plated bone and occasional lameness. Radiographically there was perfect union of the fractured radius also. The surgery was performed under general anaesthesia. Prior to surgery, the limb was ex-sanguniated by applying an Esmarch's bandage. On release of the bandage, a tourniquet was applied at the knee region. A craniomedial incision was made on the limb and all the screws could be retrieved without difficulty. The limb was immobilized with a Robert John's bandage and restricted activity was advised for a month.

Table 1. Anamnesis of animals under study

Dog No.	Breed	Age	Sex	Body Weight	Exciting cause of fracture	Limb affected	Duration of trauma
A1	Labrador	1year	Female	25.5 Kg	Jumping from a height	Right hind limb	1 week
A2	Non-descript	10 years	Female	7 Kg	Human inflicted	Right hind limb	5 days
A3	Non-descript	3 years	Female	13 Kg	Road traffic accident	Right hind limb	1 day
A4	German Shepherd	10 months	Female	23 Kg	Jumping from a height	Left hind limb	3 days
A5	Tibetan Terrier	6 years	Male	12.1 Kg	Fall from a height	Right forelimb	1½ months
A6	Labrador cross	2½ years	Female	19 Kg	Road traffic accident	Right forelimb	22 days
A7	Non-descript	2 years	Male	11 Kg	Fall from a height	Left forelimb	1 month
A8	Non-descript	3½ years	Female	12Kg	Human inflicted	Right hind limb	1day

Table 2. Radiographic evaluation of fractures under study

Dog No.	Bone affected	Location	Type of fracture
A1	Right Tibia and Fibula	Midshaft	Simple complete short oblique
A2	Right Tibia and Fibula	Midshaft	Transverse with serrated edges
A3	Right Tibia and Fibula	Midshaft	Multiple
A4	Left Tibia and Fibula	Junction between proximal and middle third	Short oblique with butterfly fragment
A5	Right Radius and Ulna	Junction between distal and middle third	Simple complete short oblique
A6	Right Radius and Ulna	Junction between distal and middle third	Simple complete transverse
A7	Left Humerus	Midshaft	Simple complete transverse
A8	Right Femur	Midshaft	Simple complete transverse

Table 3. Fracture assessment score of animals under study and fixation technique adopted

Dog No.	Mechanical		Biological		Clinical		Total factors considered g = (a+c+e)	Total Score h = (b+d+f)	Net fracture assessment score (g/h)	Type of plating employed
	Factors considered (a)	Score (b)	Factors considered (c)	Score (d)	Factors considered (e)	Score (f)				
A1	3	20	6	41	3	29	12	90	7.5	Compression
A2	3	29	4	21	3	30	10	80	8	Compression
A3	2	14.5	4	11.5	3	28.5	9	54.5	6	Neutralization
A4	3	20	4	21	4	27.5	11	68.5	6.2	Neutralization
A5	3	25	5	27	4	35	12	87	7.2	Compression
A6	3	25.5	5	24.5	3	29.5	11	79.5	7.2	Compression
A7	2	17	6	33.5	3	24	11	74.5	6.7	Neutralization
A8	2	19	5	31.5	3	26	10	76.5	7.65	Compression

Table 4. Implants and plating methods used in the study

Dog No.	Plate	Screws			No. of screws / fragment		Plating method
		Size	Length	Numbers	Proximal	Distal	
A1	2.7 mm DCP/ 10 hole	2.7mm	16mm	5	3	4	Compression
			18mm	2			
A2	2.7 mm DCP/ 7 hole	2.7mm	16mm	2	2	3	Compression
			18mm	3			
A3	2.7 mm Reconstruction plate/ 9 hole	2.7mm	16mm	3	3	2	Neutralisation
			26mm	2			
A4	3.5 mm DCP/ 7 hole	3.5mm	16mm	2	3	2	Neutralisation
			22mm	3			
			24mm	1			
A5	2.7 mm DCP/ 7 hole	2.7mm	14mm	1	3	2	Compression
			16mm	2			
			18mm	2			
A6	2.7 mm thin DCP/ 10 hole	2.7mm	12mm	4	6	3	Compression
			14mm	3			
			16mm	2			
A7	2.7 mm Reconstruction plate / 7 hole	2.7mm	16mm	1	3	3	Neutralisation
			18mm	3			
			20mm	2			
A8	2.7 mm DCP/ 10 hole	2.7mm	18mm	2	5	3	Compression
			22mm	2			
		3.5mm	22mm	1			
			24mm	1			
			26mm	2			

Table 5. Evaluation of functional limb usage in animals under study

Dog No.	Preoperative day	Postoperative period				Time to attain near normal gait
		1st day	15th day	30th day	60th day	
A1	10	10	5	3	*	30th postoperative day
A2	9	9	2	1	*	15th postoperative day
A3	10	10	5	3	0	30th postoperative day
A4	10	10	5	5	*	40th postoperative day
A5	10	10	5	3	0	30th postoperative day
A6	10	10	3	2	0	15th postoperative day
A7	7	7	2	1	0	15th postoperative day
A8	10	10	8	9	**	**

0 - Sound

1 - Occasionally shifts weight

2 - Mild lameness at slow trot, none while

3 - Mild lameness while walking

4 - Obvious lameness while walking, but places the foot when standing

5 - Moderate lameness, but still places foot when standing

6 - Moderate lameness, tending to shift weight off limb when standing

7 - Severe lameness

8 - Severe lameness, intermittent carriage of limb

9 - Places toe when standing, carries limb when trotting

10 - Unable to put foot on ground

*** Data not available**

**** Implant failure**

Table 6. Physiological parameters in dogs under study (Mean ± SE)

Parameters	Days of observation				
	Pre operative	1st post operative	15th post operative	30th post operative	60th post operative
Rectal Temperature (^0C)	39.08 ± 0.21	38.90 ± 0.09	38.75 ± 0.11	38.75 ± 0.11	38.82 ± 0.04
Pulse Rate (per min)	94.50 ± 2.35	91.50 ± 0.73	94.13 ± 1.34	95.25 ± 1.64	95.20 ± 1.50
Respiratory Rate (per min)	30.25 ± 1.39	32.13 ± 1.44	32.75 ± 1.81	32.50 ± 2.16	30.40 ± 0.75

Table 7. Haematological and Serum biochemical parameters in dogs under study (Mean ± SE)

Parameters		Days of observation				
		Preoperative	1^{st} postoperative	15^{th} postoperative	30^{th} postoperative	60^{th} postoperative
Haemoglobin concentration (g%)		12.65 ± 0.49	12.55 ± 0.45	12.83 ± 0.44	12.80 ± 0.50	12.76 ± 0.85
VPRC (%)		35.03 ± 1.58	34.58 ± 1.50	36.30 ± 1.24	36.35 ± 1.62	36.82 ± 2.69
ESR (mm/hr)		2.00 ± 0.60	3.25 ± 1.69	1.50 ± 0.27	1.63 ± 0.18	1.33 ± 0.33
Total Leukocyte Count ($x10^3/mm^3$)		13.01 ± 1.05	16.03 ± 1.55*	14.91 ± 1.30*	13.41 ± 1.13	12.54 ± 1.58
Differential Leukocyte Count	N %	75.75 ± 2.27	79.25 ± 2.09	77.25 ± 2.09	76.38 ± 2.11	71.60 ± 4.24
	L %	20.88 ± 1-90	18.00 ± 2.04	19.13 ± 1.92	20.25 ± 1.85	22.20 ± 3.23
	E %	2.88 ± 1.13	2.38 ± 0.38	3.00 ± 0.53	2.50 ± 0.57	4.80 ± 1.62
	M %	0.63 ± 0.32	0.38 ± 0.26	0.63 ± 0.32	0.88 ± 0.35	1.40 ± 0.40
Alkaline phosphatase (IU/ L)		127.13 ± 13.96	209.25 ± 27.82**	196.63 ± 29.81*	193.13 ± 31.07*	160 ±16.90
Calcium (mg/ dl)		9.46 ± 0.23	9.37 ± 0.27	9.26 ± 0.25	9.35 ± 0.23	9.32 ± 0.28
Phosphorus (mg/ dl)		4.99 ± 0.90	4.08 ± 0.38	5.31 ± 0.46	4.71 ± 0.30	3.64 ± 0.29

$*P<0.05$ $**P<0.01$ N - Neutrophils   L - Lymphocytes   E - Eosinophils   M - Monocytes

Table 8. Postoperative Radiographic evaluation of fractures under study

Dog No.	Postoperative days of Observation	App	Al & Ang	Activity			Apparatus			Architecture	
				Type of healing (Pri./ Sec./ Mix.)	Type of callus						
					Periosteal	Endosteal	Stability	Screw loosening	Implant usage	Soft Tissue	Bone
A1	1^{st}	G	G	NA	NA	NA	++	No	+	I	I
	15^{th}	F	F	ND	–	–	+	No	+	I	I
	30^{th}	F	F	Sec.	+	–	–	Yes	–	I	I
	60^{th}	*	*	*	*	*	*	*	*	*	*
A2	1^{st}	G	G	NA	NA	NA	+	No	+	I	I
	15^{th}	G	G	Pri.	–	–	+	No	+	I	I
	30^{th}	G	G	Pri.	–	+	+	Yes	+	I	I
	60^{th}	*	*	*	*	*	*	*	*	*	*
A3	1^{st}	G	G	NA	NA	NA	++	No	++	I	I
	15^{th}	G	G	Sec.	+	+	++	No	++	I	I
	30^{th}	G	G	Sec.	+	+	++	No	++	I	I
	60^{th}	G	G	Sec.	+	+	++	No	++	I	I
A4	1^{st}	G	G	NA	NA	NA	++	No	++	I	I
	15^{th}	G	G	ND	–	–	+	Yes	+	I	I
	30^{th}	G	G	Mix.	+	+	+	Yes	+	I	I
	60^{th}	*	*	*	*	*	*	*	*	*	*
A5	1^{st}	F	F	NA	NA	NA	++	No	+	I	I
	15^{th}	F	F	Pri.	–	–	++	No	+	I	I
	30^{th}	F	F	Pri.	–	–	++	No	+	I	I
	60^{th}	F	F	Pri.	–	–	++	No	+	I	I

Continued.......

Table 8. Continued.....

Dog No.	Postoperative days of Observation	App	Al & Ang	Activity			Apparatus			Architecture	
				Type of healing (Pri./ Sec./ Mix.)	Type of callus						
					Periosteal	Endosteal	Stability	Screw loosening	Implant usage	Soft Tissue	Bone
A6	1st	E	E	NA	NA	NA	++	No	++	I	I
	15th	E	E	Pri.	–	–	++	No	++	I	I
	30th	E	E	Pri.	–	–	++	No	++	I	I
	60th	E	E	Pri.	–	–	++	No	++	I	I
A7	1st	G	G	NA	NA	NA	++	No	++	I	I
	15th	G	G	Sec.	+	–	++	No	++	I	I
	30th	G	G	Sec.	++	–	++	No	++	I	I
	60th	G	G	Sec.	++	+	++	No	++	I	I
A8	1st	F	F	NA	NA	NA	–	Yes	–	I	I
	15th	P	P	–	–	+	–	Yes	–	I	I
	30th	P	P	–	–	–	–	Yes	–	I	I
	60th	**	**	**	**	**	**	**	**	**	**

App : Apposition
Al & Ang : Alignment & Angulation
Pri. : Primary
Sec. : Secondary
Mix. : Mixed
G : Good

E : Excellent
F : Fair
P : Poor
ND : Not Detected
NA : Not Applicable
I : Intact

– : Absent
+ : Present
++ : Good Quantity
* : Not available
** : Implant failure

Excellent : 90% to 100% contact between fracture fragments and axial malalignment in any plane less than 5^0
Good : 50% to 89% contact between fracture fragments and axial malalignment in any plane less than 10^0
Fair : 10% to 49% contact between fracture fragments and axial malalignment in any plane less than 30^0
Poor : 0 to 9% contact between fracture fragments and axial malalignment in any plane of 30^0 or more

(Rovesti *et al.*, 2006)

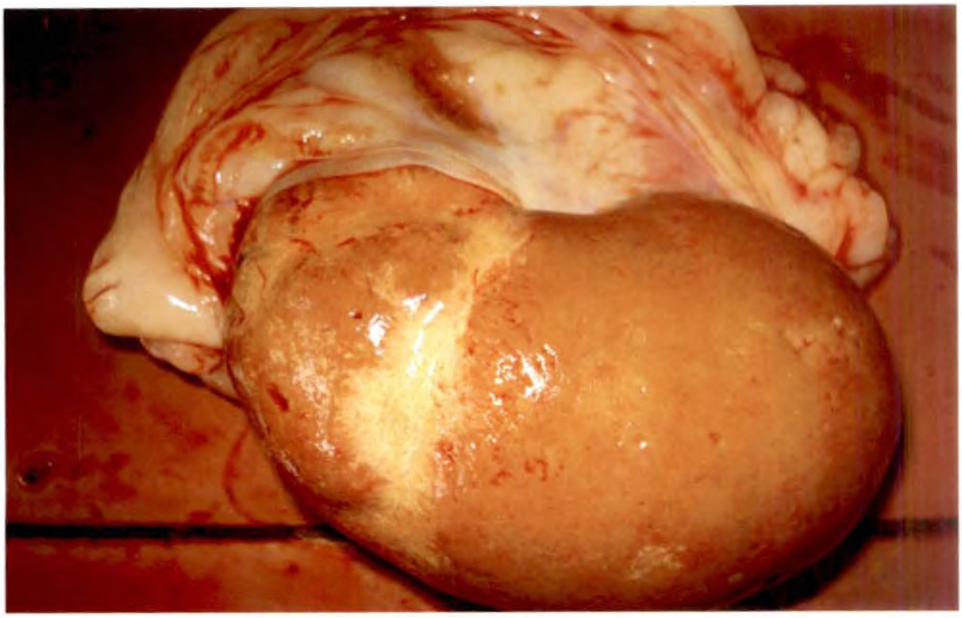


Fig. 9. Postmortem (PM) Lesion - Acute Nephritis Dog No. A4

Fig. 10. PM Lesion - Ulcerative Enteritis Dog No. A4

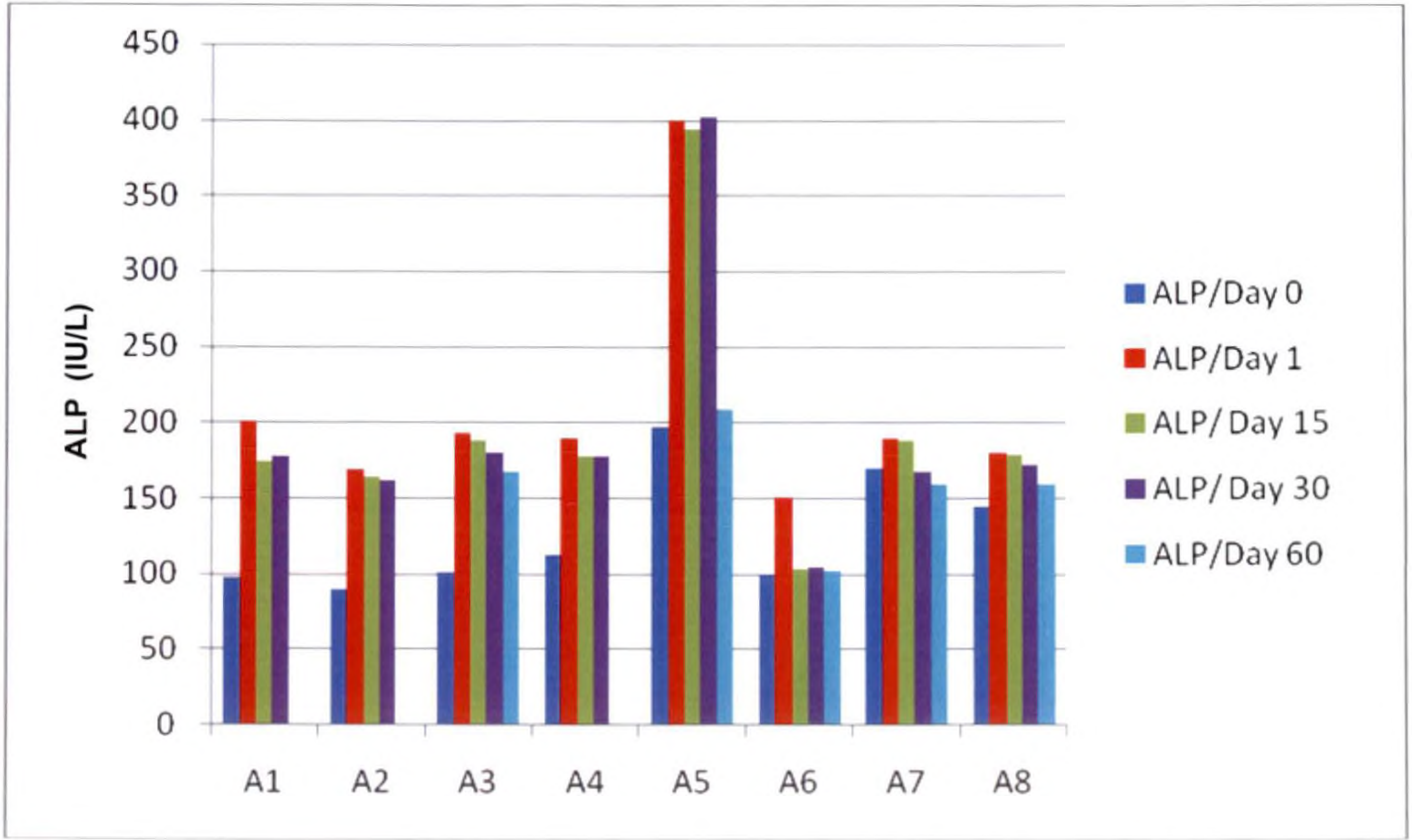


Fig. 11. Graphic Representation of Serum Alkaline Phosphatase (ALP) Levels in Dogs During the Observation Period

Plate 4. Preoperative Limb Carriage

A. Dog No. A1

B. Dog No. A2

C. Dog No. A3

D. Dog No. A4

E. Dog No. A5

Plate 5. Postoperative Functional Limb Usage - Dog No. A3

A. Preoperative Day

B. 15th Postoperative Day

C. 30th Postoperative Day

Plate 6. Postoperative Functional Limb Usage - Dog No. A6

A. Preperative Day

B. 15th Postoperative Day

C. 30th Postoperative Day

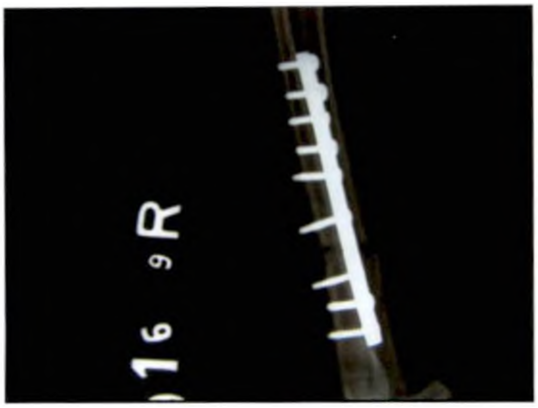
Plate 7. Skiagram Showing Radiographic Evaluation of Healing-Dog No. A6

A. Preoperative Day-Transverse Fracture
Distal Third of Radius

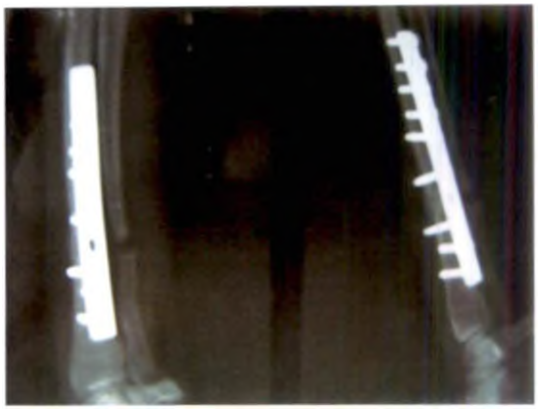
B. First Postoperative Day
Excellent Apposition & Alignment

C. 15th Postoperative Day
Radio Opaque Bone Bridging the Gap

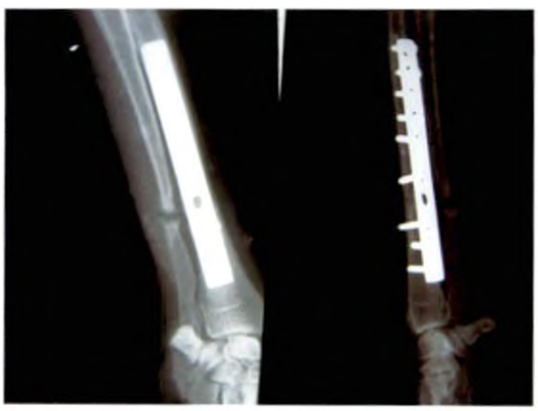
Plate 7. Continued



D. 30th Postoperative Day
Union of Trans-cortex Margins



E. 60th Postoperative Day
Fracture Gap Disappeared



F. 90th Postoperative Day
Radial Union Complete-Gap Visible
between Ulnar Fragments

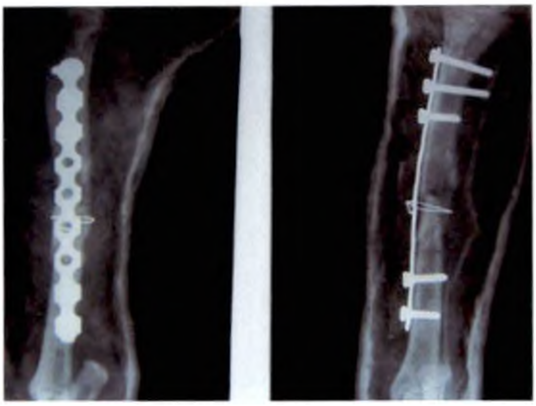
G. 120th Postoperative Day-Cortical and
Medullary Integrity of Radius
Reestablished

Plate 8. Skiagram Showing Radiographic Evaluation of Healing-Dog No. A3

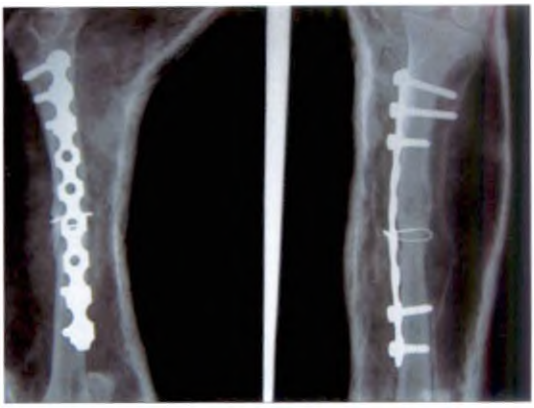
A. Multiple Fractrure Mid Shaft-Tibia

B. First Postoperative Day
Good Apposition & Alignment

C. 15th Postoperative Day
Fading of Fracture Lines with Moderate Callus



D. 30th Postoperative Day
Moderate Amount of Callus



E. 60th Postoperative Day
Fracture Gap Completely Filled by Callus

Plate 9. Skiagram Showing Radiographic Evaluation of Healing-Dog No. A7

A. Preoperative Day-Transverse Fracture
Midshaft Humerus

B. First Postoperative Day
Good Apposition & Alignment

C. Fading of Fracture Gap

Plate 9. Continued

D. 30th Postoperative Day
Extensive Callus

E. 60th Postoperative Day
Callus Bridging

F. 90th Postoperative Day
Callus Re-modelling

Plate 10. Postoperative Complications

A. Breakage of Cerclage Wire
-Dog No. A4

B. Plate Bending & Screw Loosening
15th Postoperative Day-Dog No. A8

C. Screw Pullout & Lateral Deviation
30th Postoperative Day-Dog No. A8

D. Valgus Displacement of Femur
-Dog No. A8

Discussion

5. DISCUSSION

5.1 SELECTION OF ANIMALS

During the period of study (October 2007 to March 2009), a total of 364 dogs were presented with history of lameness. Among them 152 cases were fractures. Out of these, 125 were fracture of long bones. Of the 152 fracture cases, diaphyseal fractures were 96 and represented 76.8 % of long bone fractures. From these cases, eight dogs were selected for studying plate osteosynthesis.

5.2 SIGNALMENT AND ANAMNESIS

5.2.1 Age and sex wise distribution.

The average age of incidence of long bone fracture in the study group was 3.92 years and majority of dogs were within the age group of one to 3.5 years. The sex wise distribution of the dogs was two males and six females. From an earlier survey, Phillips (1979) found that approximately 80% of fracture occurred in animals less than three years old and males were more commonly involved than females. Higher incidence of fractures among male dogs was recorded from other surveys also (Wong, 1984; Thilagar and Balasubramanian, 1988; Balagopalan *et al.* 1995 and Aithal *et al.* 1999). All of these surveys also revealed that most of the fracture victims were young animals; however majority of fractures observed by Singh *et al.* (1999) occurred in dogs between six to eight years of age.

5.2.2 Breed wise distribution.

Breed distribution among the study group was Non- descript (4), Labrador (1), German Shepherd Dog (1), Tibetan Terrier (1) and Labrador cross (1). The higher incidence of fracture among Non- descript dogs was in accordance with the findings of Thilagar and Balasubramanian (1998); Aithal *et al.* (1999) and Rani *et al.* (2004). However from a similar survey, Balagopalan *et al.* (1995) observed more number of fracture cases in Alsatians.

5.2.3 Fracture etiology

The exciting causes of fracture in the study group of animals were fall / jump from height (Dog Nos. A1, A4, A5 and A7), automobile accidents (Dog Nos. A3 and A6) and trauma inflicted by human beings (Dog Nos. A2 and A8).

Kolata *et al.* (1974) found automobile accidents as the major cause of trauma in urban dogs. Automobile accidents and fall / jump from height were the major causes of long bone fractures as observed by Phillips (1979) and Aithal *et al.* (1999). Trauma as a result of being kicked or hit with an object was a substantial cause of fracture as observed by Wong (1984).

5.2.4 Anatomical location and type of fracture

Among the dogs subjected for plate osteosynthesis, five were with fracture of hind limb and three with that of forelimb. Higher incidence of hind limb fractures were in accordance with the findings of Phillips (1979); Balagopalan *et al.* (1995); Aithal *et al.* (1999) and Harasen (2003).

Bone wise distribution were, tibia 50%, radius and ulna 25%, humerus and femur 12.5% each. Two of the tibial fractures (Dog Nos. A1 and A4) were short oblique, one multiple (A3) and one transverse (A2). Balagopalan *et al.* (1995) observed a prevalence of oblique fractures (78.2%) among total tibial fractures.

One of the radial and ulnar fractures (A5) involved the distal third of the bones and was short oblique in nature. The other was a transverse fracture at the junction between proximal and distal third (A6). This agreed with the finding of Harasen (2003) that the distal third of radius and ulna was the most common fracture site and such fractures represented 14% of total fracture cases treated.

The humeral fracture in Dog No. A7 was transverse fracture of midshaft. According to Thilagar and Balasubramanian (1988), humeral fractures were the lowest among long bone fractures in dogs. Aithal *et al.* (1999) also made similar observations and recorded the incidence as 7.71%. However in the opinion of Marcellin-Little (1998), humeral fractures were common in dogs and represented 10% of all limb fractures. According to him, about 50% of such fractures were diaphyseal fractures resulting from a major trauma.

Dog No. A8 was presented with transverse fracture of the midshaft of femur. Earlier studies made by Phillips (1979); Balagopalan *et al.* (1995) and Aithal *et al.* (1999) revealed femur as the most common among the fractured long bones. Diaphyseal fractures contributed 63.86% of femoral fractures as observed by Aithal *et al.* (1999).

5.3 BIOMECHANICAL CONSIDERATIONS

The short oblique fractures in Dog Nos. A1 and A4 were the results of compressive forces generated by jumping from a height. On landing, ground reaction forces exerted an upward thrust while the weight of animal applied a down word push. This resulted in high compressive forces and when a long bone was loaded in compression, the fracture plane would generally be at an oblique angle to the applied force (Arnoczky and Wilson, 1990). Butterfly fragments were generally produced by intervention of internally generated shear forces

Blunt trauma in the form of sharp blows or kicks also generated bending stresses perpendicular to the long axis of the bone. Transverse fractures in Dog Nos. A2 and A8 were the result of such bending stresses. Lipowitz (n.d) observed that fractures produced by pure bending forces tend to be transverse or short oblique.

High energy trauma such as automobile accidents had no limitations as magnitude or direction of application and resulted in multiple or comminuted fractures (Smith, 1985). Fracture in Dog No. A3 was a classical example of this type of high velocity trauma. Dog No. A6 was also a fracture victim of automobile accident but the fracture in this dog was transverse due to the vehicle hit exerting bending forces to the radius (Radasch, 1999).

The fractured humerus in Dog No. A7 was the result of a fall from height and eccentric loading of the bone while landing might have resulted in such a type of fracture (Hulse and Hyman, 2003).

So the fracture forces to be neutralized were compression in Dog No. A1, compression and shear in Dog No. A4, bending in Dog Nos. A2, A6, A7 and A8 and bending, shear and torsion in Dog No. A3.

5.4 PREOPERATIVE CONSIDERATIONS

5.4.1 Evaluation of the patient

Dog No. A3 was presented with history of automobile accident. Thorough clinical evaluation was carried out in this animal to rule out hidden injuries to the core body systems as advised by Roush (2005).

5.4.1.1 Physical examination

General clinical examination was carried out at the time of presentation and it provided an insight in to the general health status. Combined with laboratory investigation reports of vital haematological parameters, this helped in assessing the fitness of animal for general anaesthesia and subsequent surgery (Knowles, 1990). Evaluation of systemic factors such as age, temperament, body weight, general health and weight bearing ability of the other limbs were suggested as the initial steps in a successful fracture repair regimen (Rochat, 2001b)

The dehydration status was evaluated to correct fluid deficits prior to, during and after surgical procedures with a view to prevent potential complications associated with hypovolaemia (Brady and King, 2000).

Pain and tenderness as suggested by Piermattei et al. (2006) were exhibited by animals A1, A2, A3, A4, and A8. Not much time lag occurred between the incidence of trauma and presentation for treatment in these animals. Crepitus was also evinced by these animals on palpation. The moderate pain without tenderness evinced by Dog Nos. A5 and A6 and A7 pointed to the long time interval between the time of occurrence of fracture and presentation for treatment. Crepitus also could not be palpated in these animals. Excessive callus formation suggestive of constant motion at fracture site was observed in Dog No. A7. Wong (1984) observed that crepitus was manifested by only 20% of fracture victims and loss of function of affected limb was the most consistently noted clinical sign in fractures

5.4.1.2 Orthopaedic evaluation

Observation of animals at rest and during ambulation was effective as a diagnostic tool and gave insights into functional limb usage (Whittick and Simpson, 1990).

5.4.1.2.1 Evaluation of functional limb usage

Lameness scores as described by Sumner-Smith, (1993) were made preoperatively and used as a measure to compare with the postoperative values. This provided an estimation of functional limb usage and clinical healing of fracture.

5.4.1.2.2 Neurological examination

Test for conscious proprioception could be used as an effective tool to detect neurological deficit (Blythe, 1998). Assessment of neurologic status was essential to rule out central nervous system injuries and peripheral fracture associated injuries (Roush and Mc Laughlin, 1998). Absence of the reflex in all cases except Dog No. A7 was due to the pain and associated loss of limb function rather than neurological deficits. Considerable improvement was noticed in the first preoperative day itself in most of the animals.

5.4.2 Preoperative radiographs.

The preoperative radiographs were used initially to classify the fracture according to its appearance as to type, location and position of fracture fragments (Biery, 1985). Information obtained from the preoperative radiograph was used to plan the treatment and to give owners a prognosis and an estimate of treatment costs. Radiographic views of the normal contra lateral bone was also taken whenever possible as it was useful for comparative purposes, particularly when dealing with a severely comminuted fracture as they gave information about original direction and shape of bone. (Langley-Hobbs, 2003)

5.4.3 Preoperative stabilization of the patients

Cleansing and debridement of the small penetrating wound observed in Dog No. A3 helped to prevent secondary bacterial complications. According to Johnson (1999), open wounds associated with fractures could act as a source of contamination during surgery and ultimately might result in osteomyelitis.

Satisfactory pain relief could be obtained by the administration of meloxicam at the dose rate of 0.2 mg/kg body weight followed by oral route in Dog No. A4. Preoperative administration of meloxicam was a safe and effective method of controlling pain in dogs for up to 24 hours after surgery (Deneuche *et al.* 2004). Prophylactic antibiotic administration with ceftriaxone at the dose rate of 20 mg/kg body weight was also done in this dog since it was presented with hyperthermia and contusion and bruises near the fracture site. However postoperative wound dehiscence was noticed in this dog which raised question about the usefulness of such a measure. Prophylactic antibiotic administration was advised by Houlton and Dunning (2005) only when the length of surgical procedure extended beyond 90 minutes.

Preoperative immobilization of the fractured limbs was done in Dog Nos. A1, A2, A4, A5, A6 and A7 since elective surgery were undertaken in these animals. Rochat (2001b) advised temporary fracture immobilization to prevent further soft tissue injury and to make the animal more comfortable.

5.5 DECISION MAKING AND IMPLANT SELECTION

5.5.1 Fracture assessment score

Mechanical biological and clinical parameters were judiciously combined for deducing the fracture assessment score for each animal under study. The individual score could be effectively used for selecting the mode of application of plate (Piermattei *et al.*, 2006). In the opinion of Johnson and Hulse (2002), fracture fixation represented a timing race between implant failure and fracture healing. Mistakes often occurred when implants were selected solely based on the observation of fracture configurations as seen on a preoperative radiograph. Favourable clinical outcome were obtained in all animals except Dog No. A8. Even in this dog, factors other than the selection of fixation method based on fracture assessment score contributed to implant failure.

5.5.2 Preoperative fracture plan

The preoperative fracture plan helped considerably in the initial selection of plate and screws in Dog Nos. A3, A6 and A7 (Houlton and Dunning, 2005). It also helped to procure sufficient numbers of screws during pre-surgical period itself so that last minute replacement with less suitable ones could be avoided. In A8, no fracture plan was prepared due to emergency nature of the case and associated shortcomings were also observed in this dog. Consulting with the veterinary implant chart further helped in the selection of precise implants prior to surgery as reported by Jones (1994). The weight of Dog No. A1 was 25.5 kg and the correct plate to be used as per the chart was 3.5 mm DCP; instead a 2.7mm/ seven hole DCP was used since it was the sole plate available that almost matched the requirement. The good alignment and apposition observed in the immediate postoperative radiographs were not seen in the subsequent radiographs as evidenced by reduction in contact between fragments.

5.5.2.1 Screws

Use of non self tapping cortical screws necessitated pre-tapping of screw holes (Schatzker, 1991). Use of screw sizes greater than 25% to 30% of the diameter of the bone were avoided to prevent reduction in bone strength and stress concentration at the screw holes as observed by Conzemius and Swainson (1999). Consultation with AO/ASIF published screw and drill bit chart aided in initial selection of precise screws and appropriate drill bits in dog numbers A1, A2, A3, A4, A5 and A7 (Jones, 1994).

5.5.2.2 Plates

DCP was applied in compression mode in Dog Nos. A1, A2, A5, A6 and A8, and in neutralization mode in Dog No. A4. This classification was solely based on plate function as observed by DeYoung and Probst (1992).

Reconstruction plates were used in neutralization mode in Dog Nos. A3 and A7. As per the implant reference chart, 2.7 mm DCP was the implant of choice for Dog No. A3, instead a, 2.7mm reconstruction plate was used. The plate was selected since it could be easily cut and contoured to the 'S' shaped curvature of the bone (Koch, 2005). The low body weight of the animal compensated for the reduced strength of the plate. Reconstruction plates were more versatile in that they worked well in areas were plate contouring was difficult and the oval screw holes increased the versatility of the angle at which screws could be placed, however they were less resistant to bending forces and the screw holes provided some axial compression too (Conzemius and Swainson, 1999). Reconstruction plates were weaker than equivalent sized DCP (Roe, 2003). This was evidenced by the mild bending of plate observed in Dog No. A7.

5.6 EVALUATION OF THE TECHNIQUE

5.6.1 Anaesthetic protocol

Anaesthetic protocol used in the study was satisfactory. Use of xylazine at the dose rate of 1 mg/kg body weight achieved good sedation as observed by

Raghavan *et al.* (1979). Ayyappan *et al.* (1999) also obtained satisfactory sedation with xylazine in a dog premedicated with atropine for compression plate fixation for comminuted tibial fracture. The induction of general anaesthesia with ketamine and its maintenance with intravenous administration of a mixture of equal volumes of xylazine and ketamine in small increments of 0.2 ml and diazepam at the dose rate of 0.2 mg/kg body weight provided sufficient surgical plane of anaesthesia with muscle relaxation throughout the period of surgery. Rapid induction of anaesthesia with absence of pedal reflex was observed in dogs by the combined use of xylazine and ketamine by Moens and Fargetton (1990). Same anaesthetic protocol as in the present study was satisfactorily used for external skeletal fixation in long bone fractures by Julie (2005).

Premedication with xylazine at the dose rate 0.5mg/kg intramuscularly and subsequent administration of propofol as a bolus dose at the rate of 4 mg/kg body weight intravenously provided smooth induction of general anaesthesia to a plane suitable for endotracheal intubation in Dog No. A6. Adetunji *et al.* (2002) observed rapid induction of anaesthesia by intravenous bolus administration of propofol and recovery with very infrequent occurrence of unusual reaction in dogs premedicated with xylazine. The maintenance of anaesthesia by administration of a mixture of isoflurane and oxygen through a Bane's circuit system produced good analgesia and muscle relaxation suitable for surgery. Solano *et al.* (2006) anaesthetized dogs by administration of a mixture of isoflurane in oxygen flow rate of 15ml /kg body weight/minute. The anaesthetic protocol adopted in the pregnant animal did not cause any problem with pregnancy and the animal whelped four healthy pups.

5.6.2 Preparation of site

The suspension of fractured limb from an intravenous fluid stand provided satisfactory clipping of both medial and lateral sides. The use of electrical clipper helped to reduce skin abrasions and subsequent bacterial proliferation (Penwick 1985). The surgical site preparation was done after administration of preanaesthetic medication to reduce the chance of infection as suggested by Weese (2008). According to Brown *et al.* (1997), surgical sites clipped before anaesthetic induction were three times more likely to be infected than sites clipped after induction.

5.6.3 Preoperative traction

Gradual progressive traction and counter-traction was advised by Johnson (2003) to counteract muscle contraction and facilitate reduction of fractures. The factor having the greatest influence on the weight and duration of traction required to obtain fracture reduction was the time interval between trauma and surgical intervention (Rovesti and Peirone, 2002). Placing the animal in dorsal recumbency and hanging the fractured limb for 10-30 minutes adequately fatigued the muscles as observed by Aron (1998).

5.6.4 Surgical approach

Cranial medial approach suggested by Seaman and Simpson (2004) provided adequate exposure of the fractured bone in tibial fractures. Both cranio medial and cranio lateral approaches were used in radius and ulna fractures. The craniolateral approach prescribed by Toombs (2005) was used in Dog No. A5. The cranio medial incision recommended by Milovancev and Ralphs (2004) was used in Dog No. A6 and found to be more advantageous since the radius was subcutaneous in this area and good exposure of diaphysis was achieved without much muscle elevation. Incising the fascia of the abductor pollicus longus and retracting this muscle in a craniolateral direction provided a better exposure of distal radius as observed by Sardinas and Montavon (1997). The cranio-medial approach suggested by Piermattei and Greely (1966) provided satisfactory exposure of humeral shaft in Dog No. A7. But in this animal further extension of incision was necessary to debride the exuberant callus. Lateral approach suggested by Eaton-Wells *et al.* (1990) allowed satisfactory exposure of femur in Dog No. A8.

5.6.5 Fracture reduction

The guidelines suggested by Mast (1991) were followed to achieve anatomical reduction of fragments. Reduction of oblique fractures were difficult and time consuming since much effort was required to overcome the muscle contraction as opined by Johnson and Hulse(2002). The levering technique suggested by Piermattei *et al.* (2006) was employed to achieve satisfactory reduction in Dog No. A1. Maintaining the fragments in reduction while plate was applied was the next difficult step. This was achieved by applying a bone holding forceps at an angle to the reduced fragments to keep them in position.

Cranial displacement of the proximal fracture fragment made reduction of fragments difficult in Dog No. A2. Slow manual distraction of the segments using two bone holding forceps aided in achieving eventual muscle fatigue and facilitated reduction. Trimming of the serrated end were also done to get proper alignment.

Anatomical reconstruction of the multiple fragments employing a lag screw failed in Dog No. A3. The far cortex began splitting while the screw was being tightened. Difficulties encountered in anatomical reconstruction of comminuted fractures were well documented earlier (Johnson *et al.* 1998). Eventual reduction in this animal was achieved by fixing the contoured plate to the proximal segment and securing the loose fragment to the plate by a cerclage wire (Johnson, 2003).

Application of a bone holding forceps at an angle to the fracture line and gentle manipulation suggested by Piermattei *et al.*(2006) was satisfactorily employed in Dog No. A4 for fracture reduction.

Fracture reduction in Dog No. A5 was also difficult since the fracture had already progressed to nonunion with fusion of medullary cavity. Extensive debridement and freshening of fracture margins as suggested by Denny (1990) were to be undertaken in this dog. In Dog Nos. A5 and A6, the plate was first attached to the distal fragment and secured with screws. Then reduction was achieved with the aid of the plate as advised by Johnson (2003).

The humeral fracture in Dog No. A7 was progressing to malunion with extensive periosteal callus formation. This required a through debridement and freshening. The reduction was achieved by toggling.

Even though fracture could be reduced satisfactorily, plate fixation was difficult in Dog No. A8. Keeping the fragments in reduction while plate was being applied to the bone was also cumbersome in this animal due to excessive muscle contraction.

5.6.6 Contouring of plates

Contouring of plate to the anatomical surface of the bone generated enough friction at the implant bone interface and protected the screws from bending or shear load. Judicious use of bending irons and radiograph of the contralateral limb as a template as suggested by Jones (1994) facilitated satisfactory contouring of plates in Dog Nos. A3, A6 and A7.

Reconstruction plates used in Dog Nos. A3 and A7 had the added advantage of greater flexibility for proper contouring than DCP (Roe, 2003). Contouring of stiff plates to the anatomical curvatures of humerus was difficult (Marcellin-Little, 1998). Medial approach was often recommended in such cases since the bone plate could be applied with minimum contouring (Tomlinson, 2003). However, Simpson (2004) observed that the chances of damage to brachial vessels and nerves were more with medial approach making it less favourable. Use of reconstruction plate solved these problems as it was less stiff and could be contoured with minimum effort. The low body weight of the animal compensated for the reduced strength of the plate.

5.6.7 Prestressing of the plates

Prestressing of the plates ensured that a 1-2 mm gap existed between the plate and bone over the fracture before screw tightening. Once the screws were tightened, the plate was elastically straightened and adequate compression of both cortices was achieved (DeYoung and Probst, 1993). In Dog No. A3, prestressing was avoided since in multiple fractures it would change the axis of the bone and might result in malunion or failure of the implant through bending as observed by Schatzker (1991).

5.6.8 Application of plates

Plates used in compression mode were placed on the tension side of bone as instructed by Nunamaker, (1985). Even though the theoretical tension band side of tibia was the cranial lateral surface, plates were applied on the cranial medial surface in Dog Nos. A1and A2 as lateral approach was more difficult in this bone

(DeYoung and Probst, 1993). Moreover the surface that lay opposite to area spanned by most muscle mass could be considered as the tension band surface for all practical purposes.

Plate was applied to the cranial surface of radius in Dog No. A5. At the distal radius, the synovial sheath of both tendons of extensor carpi radialis muscles tightly adhered to the middle groove of radius. So when plate was placed on the cranial surface, the tendons were over-riding the plate and screws. Moreover, the abductor pollicus longus muscle had to be severed for placement of plate on the cranial surface. All these resulted in technical difficulties as observed by Wallace *et al.* (1992).

The medial approach to the radius was used in Dog No. A6. This approach had several advantages over the previous method. During surgery, the animal could be placed on lateral recumbency with the fractured limb down. This allowed greater ease of fracture reduction and placement of plate. The chance of iatrogenic placement of a screw in to the ulna was avoided. The retraction of extensor tendons was also avoided (Sardinas and Montavon, 1997).

The 2.7 mm DCP was applied to the lateral surface of femur in Dog No. A8 since this was the tension band surface.

Neutralization plates used in Dog Nos. A3, A4 and A7 were also applied to the tension side of the bones as observed by Piermattei *et al.* (2006). In Dog Nos. A3 and A4 this was the cranial medial surface of tibia and in Dog No. A7, the cranial surface of humerus.

5.6.9 Plate fixation

5.6.9.1 Dynamic compression plating

Use of low speed high torque power drill and drill guides reduced wobbling during the drilling process as observed by Nunamaker (1985).

In dynamic compression plating, use of the loaded/eccentric drill guide ensured that the screw hole was drilled offset from the location where the screw head was designed to sit in the plate (Conzemius and Swainson, 1999).

Pre-tapping of the drill hole allowed screws to be inserted with less torque. Pre-tapped drill holes also guaranteed easy removal and re-insertion of screw in the same hole without the danger of cross threading the hole. Pre-threaded screw hole also allowed selection of a screw of correct length so that an excessive amount of screw shaft was not exposed on the far side of the cortical bone before full thread engagement of the bone had occurred (Nunamaker, 1985).

In Dog Nos. A1, A2 and A6, placement of plate on the fractured bone with the pre-stressed portion directly above the fracture line ensured adequate compression of the trans-cortex surface (Schatzker, 1991).

In Dog Nos. A1, A5 and A8 technical difficulties were encountered to maintain the fragments in reduction while eccentric hole was drilled. This could be overcome to some extent by holding the fragments at an angle with bone holding forceps and then drilling through the eccentric drill gauge. The best way to overcome such difficulties was securing the plate to the proximal segment with plate holding forceps (Houlton and Dunning, 2005).

In Dog No. A8, the threads were stripped during the tapping process as evidenced by the screw becoming loose while being driven through the transcortex. This was rectified by the use of an oversized tap (3.5mm) and screws as advised by Turner (2002).

5.6.9.2 Neutralization plating

The well acclaimed method of achieving interfragmentary compression was the use of lag screws (Denny, 1991); however cerclage wires also could be used to anatomically reconstruct fracture fragments in comminuted fractures as observed by Hulse *et al.* (1997)

In Dog No. A3, multiple fracture lines were present. Attempts to anatomically reconstruct the fragment by inserting a lag screw failed as the far cortex began to split. The loose fragment was stabilized using a cerclage wire and reconstruction plate applied in neutralization mode.

In Dog No. A4, the fractured tibia had a butterfly fragment. In this animal also the fragment was stabilized with single cerclage wire and DCP applied in neutralization mode. In both these cases the screw holes were drilled using the neutral drill gauge and screws inserted without compression (Conzemius and Swainson, 1999).

In Dog No. A7, some degree of axial compression could be achieved by tightening the screws in the oval screw holes of the reconstruction plate.

5.6.10 Intraoperative lavage of surgical site

Continuous flushing of the drill bit with gentamicin mixed normal saline during the drilling process helped to prevent heat induced bone necrosis and subsequent poor bone-thread interface. Constant flushing with pressure also helped to maintain a clear field free of bone debris, thus minimizing the possibility of infection. (Egger and Whittick, 1990)

5.7 POSTOPERATIVE MANGEMENT

5.7.1 Postoperative immobilization

The fractured limbs were immobilised in all animals following plate application and closure of the surgical incision with a view to restrict the activity. Chapman *et al.* (1989) observed that when patient compliance was poor, protection of the limb in a long plaster cast was necessary after plating until the fracture had united.

Although plate fixation allowed early pain free movement, refractures might occur through overuse of the limb during the recovery period (Hunt *et al.* 1980). POP had the advantages like easiness of application, radiolucency and the removal was comparatively easy (Langley-Hobbs, 1996). Robert John's bandage was especially useful for temporary immobilization of surgically repaired fractures distal to elbow and stifle. It was comfortable, restricted motion and reduced soft tissue swelling (Weinstein and Ralphs, 2004).

5.7.2 Postoperative pain management

Postoperative analgesia was indicated to reduce post surgical morbidity and for animal welfare. Moreover postoperative analgesia helped in early active use of affected limb (Millis 2004). Use of Meloxicam at the dose rate of 0.2mg/kg body weight was effective in providing immediate postoperative analgesia as observed by Deneuche *et al.* (2004). Tramadol at the dose rate of 2mg/kg body weight intravenously twice daily was an effective alternative to NSAIDS in Dog No. A3. This was in agreement with the findings of McMillan *et al.* (2008).

Haloperidol was administered to Dog Nos. A7 and A8 which showed a tendency for mutilation of casts at the dose rate of 0.2 mg/kg body weight intramuscularly once daily for three days to provide postoperative analgesia and sedation. Immediate postoperative sedation was advised by Hickman (1966) to prevent mutilation of dressings. The disadvantage observed was reduction in food and water intake which could be managed by parenteral administration of fluids.

5.7.3 Postoperative antibiotic therapy

The postoperative antibiotic regimen with ceftriaxone was effective in preventing secondary bacterial complications in all dogs except Dog No. A4. Carter (1966) advised the administration of antibiotics in cases where skin continuity was lost either due to an open fracture or due to surgical procedure.
Rochat (2001a) also recommended use of antibiotics in clean orthopaedic surgical procedures with implant placement and severe trauma especially when they last for more than two hours. A first generation cephalosporin was the drug of choice.

Agrawal *et al.* (2006) opined that due to the use of implants for open reduction and internal fixation which were foreign bodies to the body, orthopaedic trauma surgery was at a grave risk of microbiological contamination and infection. Gram negative infections were emerged as the major threat in orthopaedic cases and ceftriaxone and cefaperazone were found to be the most effective antibiotics against them.

5.8 POSTOPERATIVE PATIENT EVALUATION

5.8.1 Clinical evaluation

5.8.1.1 General condition and dehydration

General body condition and demeanour of all the animals were satisfactory and remained unchanged throughout the observation period. However Dog No. A4 died 1½ months after surgery due to reasons other than fracture management. The postoperative lesions were suggestive of acute ulcerative enteritis and nephritis. None of the dogs exhibited signs of dehydration.

5.8.1.2 Evaluation of pain at fracture site

Behavioural changes were used as an indicator of postoperative pain since palpation could not be employed due to the cast (Dyson, 2008). The early signs of pain exhibited by Dog No. A3 such as vocalization and guarding the affected limb were due to the soft tissue trauma and gradually subsided by the eighth postoperative day. Pain symptoms evinced by Dog No. A4 was associated with wound dehiscence and subsided by the thirtieth day. Persistence of pain after healing of skin wound was considered as implant related. Gentle palpation of surgical site on the fifteenth day in animals A2, A5, A6, and A7 elicited no pain response and indicated stability of the fixation. True pain associated with implant failure was only manifested by Dog No. A8 from the eighth day onwards.

5.8.1.3 Functional limb usage evaluation

Functional limb usage was evaluated by grading the lameness as suggested by Braden and Brinker (1976). A, 0 to 10 grading system developed by Sumner-Smith (1993) was employed for grading the lameness. Most of the animals were presented preoperatively with a lameness score of 9 or 10 (Table 5). But considerable improvement with partial weight bearing on the fractured limb followed later by full weight bearing was observed within a month in majority of the animals following plate fixation. Only exception was Dog No. A8 in which implant failure occurred following disruption of the POP cast.

Among the four tibial fractures stabilized with plates Dog No. A1 was a comparatively heavier animal with a body weight of 25.5Kg with an initial lameness score of 10. Following plate osteosynthesis, partial weight bearing was exhibited by this animal from the eighth day onwards which continued in the same stage up to fifteenth postoperative day. Immediate postoperative radiograph revealed formation of a butterfly fragment which was not observed in the preoperative radiograph. Apposition between the fragments was about 80%. All these factors might have contributed to the high lameness grade observed during the immediate postoperative period. However considerable improvement was noticed on the thirtieth day.

Dog No. A2 showed partial weight bearing on the second postoperative day itself with placing the foot while standing but exhibiting obvious lameness while walking with a lameness grade of six. Ayyappan *et al.* (1999) observed partial weight bearing from second postoperative day onwards in a dog following plate osteosynthesis.

Dog No. A3 was the victim of an automobile accident and this high velocity trauma had imparted considerable soft tissue injury also. Multiple fractures of tibia in this animal was stabilized with cerclage wire and plate applied in neutralization mode. Partial weight bearing was exhibited by this animal on the eighth postoperative day. The high lameness score exhibited by this animal for the first fifteen days could be attributed to the soft tissue trauma rather than failure of the comparatively weaker reconstruction plate. Almost normal functional limb usage was regained by this animal on the thirtieth day which progressed to sound limb usage by the sixtieth day.

Dog No. A4 was presented on the eighth postoperative day with a lameness score of four. On removal of plaster cast, wound dehiscence was observed with sanguineous discharge. The lameness score remained the same up to the thirtieth day during which it was under treatment for the secondary wound infection. The high morbidity caused by the broken cerclage wire and loss of soft tissue integrity could be considered as reasons for the delayed weight bearing on the fractured limb (Stiffler, 2004). After removal of the broken wire, sudden progressive improvement was observed and by the fortieth day almost normal weight bearing was observed as reported by the owner over telephone.

Dog No. A5 was presented with non-union fracture of radius and ulna and with a lameness score of 10. Moderate lameness (a score of five) was exhibited by this animal for the first fifteen days. The condition had improved to a score of three (mild lameness) by the thirtieth day. Sound usage of limb was observed on sixtieth day. Blaeser *et al.* (2003) had suggested limited enbloc osteotomy and compression plate fixation as a treatment for biologically inactivated non unions.

Dog No. A6 exhibited a high lameness score of ten at the time of presentation. Partial weight bearing was observed on the second postoperative day itself which progressed to a score of three by day 15. Yuvraj *et al.* (2007) reported similar results for radial fractures stabilised with DCP.

Dog No. A7 was presented with history of fall about one month back and the fracture of humerus in this dog was progressing to malunion with exuberant callus formation. Lameness score of seven exhibited at the time of presentation progressed to two by the fifteenth postoperative day. Rigid stabilization with plates was a suggested treatment for malunion (Jackson and Pacchiana, 2004).

Partial weight bearing was exhibited by Dog No. A8 on the second postoperative day following plate osteosynthesis, but severe lameness was exhibited by this dog soon after self mutilation of the cast on the eighth postoperative day. The lameness was continued through the fifteenth postoperative day and the corresponding radiograph revealed plate bending and screw loosening. Considerable valgus malalignment was also evident. By the thirtieth day implant failure was almost complete and the animal was carrying the limb. According to Turner (2002), failure to securely fit the plate to proximal and distal bone ends and inadequate contouring would result in mal-alignment, impaired joint and limb function and possible impaired bone healing.

5.8.1.4 Neurological examination

Test for conscious proprioception could be used as an indicator of neurological deficit that might have occurred due to the original trauma resulting in fracture or as a sequlae of surgery and implant placement. The normal reflex observed in Dog Nos. A1, A2, A6, A7 and A8 on the 2nd postoperative day were suggestive of intact peripheral nervous system. The delay observed in A3 and A5 and A4 could be attributed to the soft tissue trauma rather than neurological deficit.

5.8.2 Physiological parameters

Respiratory rate (per minute), pulse rate (per minute) and temperature (^{0} C) were within the normal range preoperatively except mild hyperthermia noticed in Dog No. A4 which responded to preoperative antibiotic treatment. The values were within the normal range throughout the observation period. The mucous membrane was pale roseate preoperatively in all except Dog No. A1, in which it was congested. This could be due to the peripheral vasoconstriction associated with trauma and pain. The colour returned to normal on the first postoperative day. The normal range of physiological parameters observed during the postoperative period indicated that surgery had no deleterious systemic effect in any of the animals under study.

5.8.3 Haematological evaluation

Total leukocyte count showed significant increase on the first postoperative day and remained so up to the 15th postoperative day. By the 30th day, the value returned to the preoperative figures. This could be attributed to the cellular events occurring in association with surgery and associated trauma. The haemoglobin concentration, differential leukocyte count, erythrocyte sedimentation rate and volume of packed red cells values registered no significant changes during the period of observation. From similar studies, Julie (2005) and Remya (2008) observed a significant decrease in haemoglobin and VPRC values throughout the postoperative period than the preoperative figures.

5.8.4 Serum biochemical parameters

Alkaline phosphatase (ALP) levels showed a highly significant increase on the first postoperative day and the increase was significant on the 15th and 30th day. Serum calcium and phosphorus values remained without significant variation during the observation period. Singh et al (1976) observed no correlation between fracture healing and the levels of serum calcium and phosphorus; but a significant increase in serum concentration of ALP was observed on the seventh and 14th post surgical days respectively. Hegade et al (2007) observed a significantly higher level of serum ALP on the operative day than the rest of postoperative days. Serum calcium and phosphorus levels fluctuated within normal limits. Komnenou *et al.* (2008) observed that serum ALP activity increased depending on the size of callus with maximum level reaching on the 10th day following surgery and returned to normal within two months in case of healed fractures. Julie (2005) and Remya (2008) observed that serum alkaline phosphatase level showed a significant increase during the first two weeks after fixation of fracture and then showed a significant decrease by the fourth week. Unlike the present study, these earlier workers also found a significant decrease in serum calcium concentration by the fourth week.

5.8.5 Radiographic evaluation

In the present study, radiographic evaluation was carried out preoperatively, immediate postoperative and thereafter on the 15^{th}, 30^{th} and 60^{th} postoperative days. Egger and Whittick (1990) advised postoperative radiographic monitoring of fracture at every two weeks. If it was not possible due to client inconveniences, the radiographic monitoring might be made every three to four weeks. When combined with clinical evaluation of the patient, radiographic study provided maximum information regarding status of the fracture healing process and dictated the removal of immobilization devices if necessary.

A thorough assessment of immediate postoperative radiograph could be done by evaluating apposition, alignment, angulation and apparatus ('four A's) as observed by Langley- Hobbs (2003). Follow up radiographs were compared with the previous one to determine the dynamics of bone healing. Evidence of bone formation and implant position were appraised to detect instability ('six A's - apposition, alignment, angulation, apparatus, activity and architecture).

5.8.5.1 Apposition

5.8.5.1.1 First postoperative day

Apposition between the fracture fragments was adequate in majority of the cases. Even though contact between fragments was good in Dog No. A1, a butterfly fragment was seen originated from the main distal fragment. Since this was not seen in the preoperative radiograph, it could be presumed that driving of a screw through microscopic fissure lines present in the fracture had resulted in the formation of this fragment. Screws driven through a fracture or fissure line might result in distraction of the fragments, worsening of the fissure or stripping of screw threads. Passing the screw through only one cortex or leaving a screw hole empty might have averted this short coming as suggested by DeYoung and Probst (1993). The high lameness grade exhibited by this animal during the immediate postoperative period could most probably be due to the butterfly fragment and associated instability.

In Dog No. A2 also, cent percent compression could not be achieved between the fragments. The fractured tibia in this animal had serrated ends which were to be freshened. Difficulty was encountered in maintaining the fragments in reduction while drilling the screw holes in this dog. This might also have contributed to the almost 2mm gap observed between the fragments. In such cases, Houlton and Dunning (2005) suggested the use of a self retaining plate holding forceps to maintain the fragments in reduction.

Good contact between the fragments was observed in Dog Nos. A3 and A4 where cerclage wire was used for reconstructing the comminuted fragments. Good initial apposition of fractured fragments with cerclage wire and neutralization plate combination was observed earlier by Saravanan et al (2002).

Apposition between fragments was only fair in Dog No. A5 where compression plating was used to stabilize non union of radius and ulna (10-49% contact). The fracture was 1½ month old and a non union so that extensive debridement of the excessive periosteal callus and freshening of the fused medullary cavity had to be undertaken before reduction of the fracture. In old fractures, reduction was more difficult due to the resistance offered by contracted muscles and fibrous callus (Smith, 1985). Moreover it was a small Tibetan terrier and the fracture was on the distal third of radius and ulna. So difficulties described by Wallace *et* al. (1992) were encountered during application of plates. To overcome these defects the plate was placed on the medial aspect of radius through a cranial medial approach in Dog No. A6 with excellent outcome.

Use of reconstruction plate in neutralization mode provided good apposition between the fragments in Dog No. A7.

The apposition between fragments was only fair in Dog No. A8 as evidenced by a medial displacement of the distal fragment.

5.8.5.1.2 Fifteenth postoperative day

The apposition between fragments was maintained in comparison to the previous radiograph in majority of animals. But an increase in the gap between fragments was seen in Dog No. A1. This was related to implant instability rather than due to osteoclastic resorption of necrotic bone at the fracture margins as observed by Sande (1999). Medial displacement of butterfly fragment was also observed which also pointed to implant instability.

In Dog No. A8, the almost complete loss of contact between fragments observed could be attributed to plate bending and screw loosening.

5.8.5.1.3 Thirtieth postoperative day

Thirtieth postoperative day radiograph also revealed an increase in the fracture gap in comparison to the 15th day radiograph in Dog No. A1. This was due to further medial migration of the butterfly fragment indicating micomotion within the fracture.

In Dog No. A8, the apposition between the fragments was almost completely lost. The eccentric bending stresses had their toll on the plate resulting in implant failure. Satisfactory apposition between fragments was seen maintained in all the other animals.

5.8.5.1.4 Sixtieth postoperative day

Dog Nos. A1and A2 were not available for review as the owners did not bring them on the 60th day. Instead these animals were brought on the 270th and 150th postoperative days respectively. Dog No. A4 died on the 45th day after surgery. The implant was removed from Dog No. A8 and replaced with an intramedullary pin on the 30th postoperative day.

In all the other dogs the apposition was more or less the same as previous radiograph.

5.8.5.2 Alignment and angulation

5.8.5.2.1 First postoperative day

The restoration of bone to its normal contour was satisfactory in most animals. Craniocaudal or mediolateral mal-alignment if any was measured by the method suggested by Dudley *et al.* (1997). Any bend in mediolateral plane (causing a valgus of varus deviation of the bone) or any degree of rotation was considered as deleterious as observed by Langley- Hobbs (2003). Cranio-caudal mal-alignment was observed in Dog No. A5 which could be attributed to the difficulties encountered during reduction and plate application.

The excellent alignment observed in Dog No. A6 could be attributed to the superiority of medial approach over craniolateral approach in plate application for distal radial fractures (Sardinas and Montavon, 1997). Valgus mal-alignment observed in Dog No. A8 was due to the technical failure associated with plate application like poor contouring.

5.8.5.2.2 Fifteenth postoperative day

Reconstructed bone had maintained its normal contour in all dogs except A7 and A8. In Dog No. A7, slight caudal mal-alignment was observed consequent to mild bending of plate; however the overall stability of fixation was good. Valgus mal-alignment had considerably increased in Dog No. A8 due to implant related instability.

5.8.5.2.3 Thirtieth postoperative day

The major fragments in Dog No. A1 retained the normal alignment while the butterfly fragment showed medial migration that could be considered as the result of mild instability. More or less satisfactory alignment was observed in Dog No. A5. The valgus displacement of the proximal fragment in Dog No. A8 showed a considerable increase in comparison to the 15th postoperative day radiograph indicating the effect of cyclical bending stresses on the faulty fixation.

5.8.5.2.4 Sixtieth postoperative day

The alignment was unchanged in all animals except Dog No. A8.

5.8.5.3 Apparatus

5.8.5.3.1 First postoperative day

Implant usage was adequate in most animals. Implant length was satisfactory as compared to the bone in all animals under study. Less than adequate screw purchase was observed in the transcortex of distal fragment in Dog No. A1. No fracture plan was prepared for this animal and so initial plate and screw selection could not be properly undertaken. Inefficient usage of depth gauge could be also considered as a contributory factor. Difficulties encountered in engaging the probe of depth gauge on the farcortex was described as the major cause for using screws of inadequate length (Egger and Whittick, 1990).

In Dog No. A7 most distal screw in the distal fragment was found not seated in the screw hole of the plate. Error in judgement while driving the screw could be attributed as the possible cause, but there was no implant instability.

Implant usage was found less than adequate in Dog No. A8. Even though the plate was of sufficient length, implant-bone contact was not sufficient to produce adequate friction at the implant-bone interface. During tapping process, stripping was observed and selected screws became loose, so oversized tap and screws were used. These screws also failed to elastically straighten the plate as per the radiograph. Failure to obtain proper plate contour to the bone surface would result in malalignment as observed by Turner (2002).

5.8.5.3.2 Fifteenth postoperative day

The implants were functioning as intended in most of the animals. In Dog No. A4, the cerclage wire was seen broken. Slight proximal migration of two proximal screws of distal fragment was also observed in this animal. This indicated the weakness of cerclage wire in providing sustained interfragmentary compression in neutralization plating. The animal was heavier (above 20 Kg.) and hyperactive too. Use of a lag screw might be a better option in this dog. Glyde and Arnett (2006) observed that cerclage wire had limited indications as an adjunct to the repair of tibial fractures for both biological and biomechanical reasons. However cerclage wire had provided adequate interfragmentary compression in Dog No. A3 when used in conjunction with reconstruction plate. Here also plate was applied in neutralization mode, but animal was much lighter than A4 (body weight13 kg.).

Mild bending of reconstruction plate was observed in Dog No. A7. This pointed to the inferiority of reconstruction plate as compared to the more rigid DCP in resisting eccentric loads to which major weight bearing bones of body were subjeeted to (Koch, 2005). The plate was used since the body weight of the dog was low (11kg) and due to the suitability of such a plate to the complex contour of humerus.

Plate bending had also occurred in Dog No. A8 with more serious outcome. The plate had bent in such a way that all the three screws had migrated from the transcortex of distal fragment and the proximal fragment showed a lateral rotation. Long bones of body were often subjected to eccentric loading by physiological forces of weight bearing exposing the plate to cyclic bending stresses. Plates were more susceptible to cyclic loading and might bend at the weak point *ie.* the screw hole (Lipowitz , n.d). The better option might have been the use of a lengthening plate which did not have screw holes on the centre or filling the screw holes in the middle with screws. The reduced friction between plate- bone interfaces at the distal fragment also might have contributed to the failure of implant.

5.8.5.3.3 Thirtieth postoperative day

Loosening of third screw of proximal fragment was seen in Dog No. A1 and resulted in micromotion of implants within the fixation as evidenced by callus formation. Loosening of second screw on the proximal fragment observed in Dog No. A2 also had resulted in implant instability. The number of screws per segment was the absolute minimum of two in this case (Piermattei *et al.,* 2006). However addition of one or two screws per fragment might have provided added stability in this case as observed by Jones (1994).

In A4, migration of most distal screws of the distal fragment was caused by the breakage of cerclage wire and resulted.reduction of plate-bone contact.

In Dog No. A8, implant failure was evident with almost complete pullout of screws from the distal fragment, and more bending of plate compared to the previous radiograph was observed. The Disruptive bending force acting on a transverse fracture could result in cyclic fatigue failure of plates as observed by Lipowitz (n.d.).

5.8.5.3.4 Sixtieth postoperative day

Adequate functioning of implants in Dog Nos. A3, A5, A6, and A7 as per the radiographs indicated good contact between the plate and bone, maintenance of adequate friction at the implant bone interface and intact screws.

5.8.5.4 Activity

5.8.5.4.1 Fifteenth postoperative day

Activity referred to radiographic evidence of bone healing. With dynamic compression plating, the objective was to achieve primary healing (Roush, 2005).

Formation of cloudy irritation callus indicated implant instability as observed by Piermattei *et al.* (2006). Radiographic evidence of healing was observed from the 15th day onwards in Dog Nos. A2, A3, A4, A5, A6 and A7. In Dog No. A2, radio-opaque bone was seen filling the fracture gap and this was an indication of primary healing as observed by Sande (1999). In Dog No. A3, the initial signs of secondary healing ie. widening of fracture gap due to osteoclastic resorption of necrotic bone tissue and moderate quantities of periosteal callus was observed.

In Dog No. A4 also widening of fracture gap was evident. In A5 primary bone healing without callus was seen between the far cortices indicating rigid fixation between these ends.

In Dog No. A6, the radiographic signs seen were suggestive of primary bone union as indicated by gradual dissolution of fracture borders and filling the fracture gap with radio opaque bone (Risselada, 2008). In this animal, the ulna showed callus bridging since it was not stabilized.

In Dog No. A7, indistinct margins, widening of fracture gap and periosteal callus proliferation indicated secondary fracture healing (Perren, 2002). Another peculiarity observed was callus proliferation throughout the length of far cortex. In this animal extensive callus debridement was undertaken on the near cortex to apply plate which might have triggered the osteoblasts.

In Dog No. A8 the fracture line was indistinct and proliferation of cloudy endosteal callus was observed indicating implant loosening (Piermattei *et al.*, 2006).

5.8.5.4.2 Thirtieth postoperative day

Periosteal callus proliferation was observed from the fracture fragments in Dog No. A1 and this could be attributed to the micro motion between the fragments. Such signs of secondary healing in compression plate fixation were to be perceived as an indication of implant instability. In animal A2 bridging callus was observed between the fragments. Absence of periosteal callus in this dog indicated that screw loosening did not cause much harm to implant stability.

In Dog No. A3, the healing was in progression with dissolution of fracture margins and gradual filling of fracture gap. This type of secondary healing was expected from neutralization plating. Factors which decide the type of healing were the stability provided by the implant coupled with the biological environment of the fracture surface as observed by Hulse and Hymen (1993).

In Dog No. A4, a mixed type of healing was observed. The margins of the butterfly fragments were completely faded and radio opaque callus had filled the gap indicating primary union. Callus proliferation was also evident around the upper margin of butterfly fragments. Different types of healing according to varying degrees of implant stability had been documented earlier (Roush, 2005).

In Dog No. A5 also, primary healing with gradual dissolution of fracture lines in the plated radius without callus formation was observed and indicated the stability of implants.

In Dog No. A6, union of transcortex margins with radio opaque bone was observed indicating primary healing and rigidity of fixation.

In Dog No. A7, periosteal callus proliferation was observed along the entire length of bone at the far cortex and fracture margins were indistinct. Endosteal callus bridging the gap was observed. Radiographic evidence of healing was hardly observed in Dog No. A8 due to the ongoing implant failure.

5.8.5.4.3 Sixtieth postoperative day

Complete bridging of fracture gap in Dog No. A3 indicated satisfactory secondary healing. Union of transcortex regions in Dog No. A5 indicated good primary healing in areas of absolute stability. Callus bridging of ulnar fragments indicated that healing was secondary in this bone. Complete disappearance of fracture gap and re-establishment of bony continuity in Dog No. A6 indicated good primary healing. In Dog No. A7 also the healing was progressing by secondary healing.

Thus from radiographic evaluation of healing, it could be concluded that primary healing occurred when the fixation was rigid and gap between fragments was nil or less than one millimetre. Even though primary healing progressed by direct bone union with minimum or no callus formation, it was much slower and heavily dependent on implant stability. The healing occurred at a faster rate in secondary healing with callus proliferation. Even when the stability of implant was not absolute, healing with callus proliferation progressed satisfactorily provided axial alignment was maintained. Similar results were obtained by earlier workers like Perren (2002).

5.8.5.5 Architecture

5.8.5.5.1 Fifteenth postoperative day

No change in size or character of soft tissue was observed radiographically. The bone density also remained unchanged on evaluation of the 15th day postoperative radiograph (Langley-Hobbs, 2003).

5.8.5.5.2 Thirtieth postoperative day

The soft tissue size and character were unchanged radiographically as compared to the 15th day radiograph. The bone density also remained unchanged.

5.8.5.5.3 Sixtieth postoperative day

The size and character of soft tissue remained unaltered in all dogs as compared to the previous radiographs.

Thus it could be concluded that plate osteosynthesis did not cause muscular atrophy or related complications in any of the animals under study. The bone density was also unchanged throughout the observation period except for mild variations associated with callus mineralization, bone formation or callus remodelling. Long term deleterious effects of rigid plate fixation such as cortical thinning, widening of medullary cavity or plate induced osteopaenia as observed Uhthoff *et al.* (2005) were not evaluated in the present study.

5.9 COMPLICATIONS

Complications associated with the study were self mutilation of cast, suture dehiscence and secondary bacterial infection, breakage of cerclage wire, plate bending and screw loosening.

5.9.1 Self mutilation of cast

Self mutilation of casts was exhibited by Dog Nos. A1, A7 and A8. This could be only perceived as a behavioural aberration as all the other five dogs accepted the cast wall. Dog No. A1 removed the cast three times by itself. Repeated applications of POP cast and Robert John's bandage were tried of no avail. Increased motion of fracture fragments were observed on the follow up radiographs and the loss of postoperative immobilization could be a contributory factor. Motion at a fracture site could lead to implant loosening (Roush and Mc Laughlin, 1998). Strict cage rest and restricted leash walking were suggested as remedial measures. Cast mutilation was exhibited by Dog No. A7 and in this animal also mild bending of plate was observed on the 15th postoperative radiograph. However no serious complications were observed. Strict cage rest and restricted exercise led to an uneventful recovery in this case also. Following internal fixation pain was rapidly diminished and the dog might try to use the limb more frequently and put more weight on it leading to malunion or other complications (Hickman, 1966). True implant failure associated with mutilation of cast was observed in Dog No. A8. The animal developed non weight bearing on the fractured limb and lateral rotation of the fragments immediately following self mutilation of cast.

5.9.2 Wound dehiscence

Wound dehiscence and suture disruption were observed in Dog No. A4. Surgical site infection was an important complication of orthopaedic surgery (Weese, 2008). Paucity of soft tissue resulted in communication of implants to outside. Closure of soft tissues could present special problems in tibial fractures because of the bulk of the appliance and lack of soft tissue required to cover the plate (Eaton-Wells *et al.* 1990). The proper dressing on alternate days and putting fresh plaster cast with a window was done to make the wound healthier. Transposition and freeing of up of soft tissues were done to re suture the wound.

5.9.3 Breakage of cerclage wire

Breakage of cerclage wire was also observed in Dog No. A4 on the 15th postoperative day radiograph. The animal was being treated for wound dehiscence and hence removal was postponed up to 30th day of observation. The most common complication of orthopaedic wiring was wire breakage and loosening. When they became loose, orthopaedic wire might interfere with bone healing or they might migrate causing significant morbidity and requiring removal (Stiffler, 2004). Use of a lag screw might have been a better choice as cerclage wires provide inadequate compression on comminuted fractures (Saravanan *et al.*

2002). Removal of the wire on the thirtieth postoperative day hastened the wound healing also.

5.9.4 Plate bending and screw loosening

The exciting cause of plate bending in Dog No. A8 was self mutilation of the POP cast on the eighth postoperative day. The dog was showing partial weight bearing from the second postoperative day itself. The over use of the limb combined with loss of protection offered by the cast might have resulted in the bending of plate. The predisposing factor might be technical failure associated with plate fixation (Turner, 2002). Premature loosening of screws and implant failure occurred in moderate and prolonged stress especially when implant selection and technique was poor resulting in micromotion (Johnson and Hulse, 2002). Failure of screws to elastically straighten the plate and fix it to the distal fragment resulted in inadequate friction at the implant bone interface and implant instability. .In such cases plates might bend when subjected to cyclic loading. The plate might bend or break under the strain, usually at a screw hole which was its weakest point. The screws might be wrenched from the bone and fracture disrupted resulting in mal-alignment.

5.10 PLATE REMOVAL

Plate removal was advised in long bone fractures after radiographic and clinical union were observed. Unexpected lameness of the limb with the plate was an indication of removal of plate (Conzemius and Swainson, 1999). Removal of plates was also recommended when they were applied to areas with limited soft tissue covering such as the radius and ulna because cold transmission might cause lameness (Johnson and Hulse, 2002). So plate was removed from Dog No. A3 when it exhibited lameness without obvious reason. The removal was undertaken aseptically with patient under general anaesthesia. The limb was immobilized with Robert john's bandage and strict cage rest and leash walking advised for a month to avoid refractures since the screw holes might act as stress risers (Nunamaker, 1985).

Summary

6. SUMMARY

The study was conducted to evaluate the effectiveness of bone plating for the treatment of fracture of long bones in dogs. Eight clinical cases of long bone fractures in dogs confirmed by radiography were the subject for the study and the cases were selected irrespective of breed, sex, age and limb affected. All dogs were subjected to detailed clinical and radiographic evaluation for determining the characteristics of the fracture like location, type and concurrent injuries. Fractures studied included four tibial and fibular fractures, two radius and ulna fractures, one humerus and one femoral fracture. Clinical, radiological and serum biochemical parameters were evaluated preoperatively and postoperatively on the immediate postoperative day and thereafter on the 15th, 30th and 60th days.

The average age of incidence of long bone fracture in the study group was 3.9 years and the majority of dogs were within the age group of 1-3.5 years. The sex wise distribution was two males and six females. The major exciting causes of fractures were fall/jump from a height, automobile accidents and malicious injuries inflicted by man. Majority of affected dogs were Non-descript. The major fracture forces were shear, compression and bending stresses. Two of the fractures were caused by high velocity trauma. Most of the animals were presented with symptoms like pain, crepitus and loss of function of the affected limb. Neurological deficit associated with fractures was also exhibited. The physiological and haematological parameters were within the normal range preoperatively and remained so throughout the observation period. Preoperative management for pain, prophylactic antibiotic coverage and preoperative immobilization were undertaken in dogs in which elective surgery was performed.

Dynamic compression plates were used in six dogs and reconstruction plates in two. DCP was applied in compression mode in five dogs and neutralization mode in one dog. Both the reconstruction plates were applied as neutralization plates. The selection of mode of application of plates was done based on fracture assessment score. The size of implants was selected consulting the standard implant reference chart and preoperative fracture plan. In Dog Nos. A3 and A4, comminuted fragments were reconstructed with a cerclage wire. Plate was

applied in the craniolateral surface of radius in Dog No. A5 which was presented with non union fracture of distal third of radius and ulna. Plate was placed in the cranio- medial surface in Dog No. A6. In all other dogs plates were placed on the tension side. The plate fixation was done by open surgery and anatomical reduction. Standard surgical approaches were employed to reach the fractured bone. Soft tissue integrity was maintained wherever possible.

Following plating, four of the animals showed slight ground contact with the fractured limb on the second postoperative day (A2, A6, A7 and A8). With the exception of Dog No. A8, all the dogs showed progressive increase in the functional limb usage and exhibited near to normal weight bearing in a month. One dog (A3) showed partial weight bearing by the eighth postoperative day and the severe lameness exhibited initially was related to the soft tissue trauma caused by the high velocity automobile accident. One dog (A1) exhibited severe lameness for the first 15 days and thereafter showed progressive improvement. Insufficient immobilization due to frequent mutilation of the cast and formation of a butterfly fragment due to the propulsion of screws through some microscopical fissure lines not evident in the preoperative radiograph were the causes. Dog No. A4 showed severe lameness for the initial 30 days due to wound dehiscence and showed sound weight bearing within 40 days. Lameness related to faulty technique was exhibited by one dog (A8) in which plate bending and screw loosening occurred following self mutilation of the cast on the eighth postoperative day.

Among the serum biochemical parameters studied, only alkaline phosphatase level increased significantly with fracture reduction and healing. Serum calcium and phosphorus levels remained without significant variation throughout the observation period.

Immediate postoperative radiograph revealed excellent alignment and apposition in Dog No. A6, good alignment and apposition in Dog Nos. A1, A2, A3, A4 and A7 and fair alignment and apposition in Dog Nos. A5 and A8. The alignment and apposition remained unchanged throughout the observation period in all dogs except A1 and A8 where it became fair and poor respectively. With the exception of Dog No. A8, the plates and screws were maintaining stability of the fixation throughout the observation period. Minor shortcomings observed were loosening of one or two screws and slight caudal displacement of fragments. In Dog No. A8, implant failure occurred with plate bending and screw loosening and subsequent pullout of screws. Primary healing with no or minimum callus was observed in Dog Nos. A5 and A6. Secondary healing with callus proliferation was observed in Dog No. A1. Healing started as primary in Dog No. A2 and progressed by callus proliferation following screw loosening. Mixed healing was observed in Dog No. A4. Secondary healing with callus proliferation was observed in Dog Nos. A3 and A7 where reconstruction plates were used in neutralisation mode. The complications observed were self mutilation of cast (Dog Nos. A1, A7 and A8), breakage of cerclage wire and wound dehiscence (Dog No. A4) and plate bending and screw loosening (Dog No. A8).

From the study, the following observations were made.

1. Early pain free ambulation was seen following plate osteosynthesis
2. Primary bone healing was observed when the reduction was perfect and the implants maintained stability
3. The healing progressed by callus proliferation when there was implant related instability or motion between fragments provided that axial alignment was maintained.
4. Compression plating could be used successfully in non union fracture of distal third of radius and ulna in small breeds of dogs.
5. Reconstruction plates were suitable for stabilization of long bone fractures in dogs of low body weight especially when the bones were with complex anatomical contours.
6. Placement of plate in cranio medial surface of radius was more advantageous in distal radius and ulna fractures as compared to cranial placement
7. Implant failure could result due to errors in judgement while the plate was being contoured, stripping of screw holes while tapping and unrestricted postoperative activity following mutilation of cast.

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EVALUATION OF PLATE OSTEOSYNTHESIS FOR THE MANAGEMENT OF LONG BONE FRACTURES IN DOGS

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ABSTRACT

Effectiveness of bone plating in the treatment of long bone fractures in dogs confirmed by radiography was evaluated clinically and radiographically in eight dogs. Dogs with fractures of diaphysis of long bones confirmed by radiography were selected and subjected to bone plating. Selected dogs were subjected to preoperative evaluation and all of them were subjected to detailed clinical, radiological, haematological and serum biochemical evaluation preoperatively and postoperatively on the immediate postoperative day, 15th, 30th and 60th post operative days.

The fractures selected were four tibial, two radio-ulnar, one humerus and one femoral fracture. Anatomically two tibial fractures were short oblique; one was transverse and the other one multiple. One of the short oblique fractures had a butterfly fragment also. The fracture of humerus and femur were transverse which involved the midshaft. One of the radial fractures was 1½ month old with nonunion involving the distal third.

Open reduction and plate fixation was done in all cases following standard AO/ASIF principles. Dynamic compression plates (DCP) were used in six dogs and reconstruction plates in two dogs. The DCP was applied in compression mode in five dogs and neutralization mode in one dog. Both the reconstruction plates were applied in neutralization mode.

The fracture reduction and plate fixation were done following standard principles. Osteosynthesis was evaluated clinically and radiographically during the observation period. Clinical evaluation was mainly based on observation for symptoms, pain and functional limb usage evaluation. Radiographs were evaluated for apposition, alignment, angulation, apparatus, activity and architecture of the fractured bone. The fracture reduction and plate fixation was satisfactory in all cases except one. Early functional limb usage with partial weight bearing was observed in four dogs. Primary healing with filling of the fracture gap with radio opaque bone was observed in dogs where the implant maintained absolute stability. Healing with callus proliferation was observed in

neutralization plating. Mixed healing was observed in cases where the implant lost some rigidity due to loosening of a screw, provided axial alignment was maintained. True implant failure was observed only in one case.

An increase in alkaline phosphatase level was observed in all dogs during the immediate post operative day and remained so up to the 30^{th} day.

Plate osteosynthesis was found effective in providing pain free early ambulation. Craniomedial plate fixation was more advantageous in distal radius and ulna fractures. Reconstruction plates were found suitable for the fixation of fractures of long bones in animals with low body weight and in cases where contouring of DCP was found difficult due to complex bone contour.