# PLATE OSTEOSYNTHESIS OF LONG BONE FRACTURES USING VETERINARY CUTTABLE PLATES IN YOUNG DOGS

**BY**

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## JANUARY - 2019

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**Dr. D. SAI BHAVANI,** I.D.No. **GVM/15-044** has satisfactorily prosecuted the course of research and that the thesis entitled **"PLATE OSTEOSYNTHESIS OF LONG BONE FRACTURES USING VETERINARY CUTTABLE PLATES IN YOUNG DOGS"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

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# CERTIFICATE

This is to certify that the thesis entitled **"PLATE OSTEOSYNTHESIS OF LONG BONE FRACTURES USING VETERINARY CUTTABLE PLATES IN YOUNG DOGS"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF VETERINARY SCIENCE** of **SRI VENKATESWARA VETERINARY UNIVERSITY, TIRUPATI,** is a record of the bonafied research work carried out by **Ms. D. SAI BHAVANI, I.D.No**: **GVM/2015-044** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.

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# LIST OF CONTENTS

# LIST OF ILLUSTRATIONS

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| @ | at the dose rate of |
| % | Per Cent |
| AO | Arbeitsgemeinschaft fuer Osteosynthefragen |
| b.i.d | Twice a day |
| b.wt. | body weight |
| cm | Centimeter |
| DCP | Dynamic Compression Plate |
| *et. al.* | and others |
| Fig. | Figure |
| EPO | Elastic Plate Osteosynthesis |
| i.m. | Intramuscular |
| IU | International Unit |
| i.v. | Intravenous |
| inj. | Injection |
| Kg | Kilogram |
| LC-DCP | Limited Contact - Dynamic Compression Plate |
| mg/kg | Milligram per kilogram |
| mg/dL | Milligram per deciliter |
| MIPO | Minimally Invasive Plate Osteosynthesis |
| mm | Millimeter |
| POD | Post-operative day |
| ORIF | Open Reduction and Internal Fixation |
| s.i.d | Once a day |
| Syp. | Syrup |
| VCP | Veterinary Cuttable Plate |

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Date

Place: Gannavaram **(D. SAI BHAVANI)**

# DECLARATION

I, **Dr. D. SAI BHAVANI**, ID. No: **GVM/2015-044** hereby declare that the thesis entitled **"PLATE OSTEOSYNTHESIS OF LONG BONE FRACTURES USING VETERINARY CUTTABLE PLATES IN YOUNG DOGS"** submitted to **SRI VENKATESWARA VETERINARY UNIVERSITY** for the degree of **MASTER OF VETERINARY SCIENCE** is the result of original research work done by me. I also declare that the materials contained in this thesis have not been published earlier.

Date :

Place : Gannavaram **(D. SAI BHAVANI)**

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## ABSTRACT


The present study was conducted on clinical cases with radius and tibia fractures in young dogs presented to the Department of Veterinary Surgery and Radiology, NTR College of Veterinary Science, Gannavaram. In the present study, among long bones highest incidence was observed in femur (40.24%) followed by radius and ulna (26.83%), tibia and fibula (25.61%) and humerus (7.32%). Medio-lateral and cranio-caudal radiographs of the fractured bone were taken for confirmatory diagnosis and implant selection. Craniolateral and medial approach were used to expose the fracture fragments of radius and tibia respectively for fracture reduction under ketamine-midazolam induction and isoflurane anaesthesia. The implants were selected according to body weight and bone size. Post-operatively, the dogs were evaluated by clinical, radiographical, lameness grading and serum biochemistry on immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days. Primary healing was observed in three cases and secondary healing was observed in three cases. Fracture healing was observed by 30$^{th}$ post-operative day in most of the cases. The dogs regained full limb functionality by 15-30 days post-surgery. All the animals regained normal return to weight bearing early (within one month) with excellent to good limb usage. Elevation in serum calcium and alkaline phosphatase levels was observed upto 15$^{th}$ post-operative day reaching a peak with gradual decline thereafter, whereas no significant variations in serum phosphorous levels were observed. Plate removal was done in all cases on 5-8 weeks post-surgery. No major postoperative complications were observed. To conclude, the VCP used was inexpensive and the EPO technique using VCP was useful for long bone fractures of young dogs making it suitable for use in Veterinary practice and the technique resulted in early weight bearing and good functional limb out come without any complications.

# CHAPTER - I

# INTRODUCTION

Fracture of the long bone is a commonly encountered orthopaedic problem in canine practice especially in young dogs (Aithal *et. al.* 1999). Radius and ulna and tibia and fibula are the most commonly fractured bones (McLain and Brown, 1982, Thilagar and Balasubramanian 1988, and Dvorak *et. al.*, 2000). The primary goal of fracture is to restore the function of the injured limb as soon as possible. Fractures can be stabilised by external coaptation or internal fixation. Various internal fixation methods used for fracture fixation are pins, wires, plates and screws for rigid anatomical fixation.

Selection of the fixation method depends on fracture configuration, the size and age of the animal, biological considerations, the number of limbs involved, concurrent musculo skeletal injuries and financial resources of the patient.

Depending on the breed, dogs reach skeletal maturity between 5 months (toy breeds) and 18 months (giant breeds) through a very rapid, biphasic growth rate. Generally, most skeletal growth occurs between 3 to 6 months of age (Cabassu, 2001 and Dejardin and Cabassu, 2008). Bones in young dogs significantly differ from mature adult bones both in structural and material properties characterised by lower strength and stiffness, as well as lower yield stress and elastic modulus. In addition, the diaphyseal cortices are considerably thinner in young dogs compared to adults which make them highly susceptible to implant failure via screw pullout (Dejardin and Cabassu, 2008). Hence, rigid anatomical internal fixation methods are not suitable for immature growing dogs. Radius fractures can be stabilised by different techniques viz., external coaptation/cast, bone plating (Ramirez and Macias, 2016), circular external skeletal fixators (Piras *et. al.,* 2011), tie-in configuration (Peirone *et. al.*, 2002) and distal radial fractures could be stabilised by mini plates or VCP or external fixator with cancellous bone graft (Harasen, 2003 and McCartney *et. al.*, 2010). However, application of bone plate and screws for radius fracture provides very stable method of fixation (Larsen *et. al.*, 1999 and Milovancev and Ralphs, 2004). Tibial fractures could be stabilised by external coaptation/cast, intramedullary pin, intramedullary pin plus cerclage wire, bone plates, plate rod (Reems *et. al.*, 2003) or external skeletal fixator based on fracture configuration.

As a result of poor outcome of intramedullary pinning and external skeletal fixation, plate osteosynthesis still remains the primary choice for diaphyseal fracture treatment in juvenile dogs. Rigid internal fixation following the basic AO principles for anatomical reduction during the early stages of growth usually gives a tragic outcome due to failure via screw pull out (Dejardin and Cabassu, 2008). The critical evaluation of the failures has led to the development of a new biological, Elastic Plate Osteosynthesis technique (EPO) for the treatment of diaphyseal fractures in puppies. This lead to the development of Veterinary cuttable plates (VCP) specially designed for internal fixation of long bone fractures in small dogs, cats and small bones in large breed dogs with thin cortices (Cabassu, 2001). The advantages of VCP are a large number of screw holes per unit length allowing for placement of multiple screws in a fragment, the narrowness and thinness of the plate and the ability to customize the thickness of the plate by stacking the VCPs of the same or different thickness (Bruse *et. al.*, 1989). It can cut to desired length.

Review of literature revealed only few reports (Bruse *et. al.*, 1989, Sarrau *et. al.*, 2007 and Heo *et. al.*, 2012) mentioning the use of VCP for stabilisation of tibial fractures in young dogs and Heo *et. al.* (2012) reported successful tibial fracture repair by MIPO with VCP. No studies could be found regarding the use of VCP for treating radius fracture in young dogs. However, many authors reported its successful use in femur fracture repair in young dogs (Bruse *et. al.*, 1989, Cabassu, 2001, Sarrau *et. al.*, 2007 and Dejardin and Cabassu, 2008).

Perusal of literature revealed paucity regarding its use for radius and tibial fracture repair in young dogs. Hence, the present study has been undertaken with the following objectives:

1) To study the incidence, etiology and clinical signs of long bone fractures in young dogs.
2) To study the technique and outcome of fracture stabilization by plate osteosynthesis using Veterinary Cuttable Plates for long bone fractures in young dogs.
3) To evaluate the postoperative bone healing following plate osteosynthesis using Veterinary Cuttable Plates by clinical, radiographic and biochemical parameters.

# Chapter – II

# REVIEW OF LITERATURE

## 2.1 ANATOMY

### 2.1.1 Anatomy of the radius

Miller *et. al.* (1964) observed that the major diaphyseal arteries enter the radius through the nutrient foramen on its caudal surface in the proximal one-third of the diaphysis. A separate nutrient artery enters the ulna on its cranial surface in the proximal one third of the diaphysis. Both nutrient arteries are branches of the palmar interosseous artery. The immature dog or cat might have diaphyseal blood supply from vessels in the pronator quadratus muscle originating between the radius and ulna on their medial surfaces.

Evans and Lahunta (2013) stated that radius was the main weight-bearing bone of the forearm. It is shorter than the ulna, which parallels it and serves primarily for muscle attachment. The body or shaft was compressed so that it presents two surfaces and two borders. Its width was two or three times its thickness. The cranial surface was convex both transversely and vertically. The caudal surface was divided into two flat to concave areas by a vertical interosseous border. The medial and lateral borders of the body of the radius present no special features.

### 2.1.2 Anatomy of tibia

Miller *et. al.* (1964) found that tibia was a long, strong bone which lies in the medial part of the crus, articulates proximally with the femur, distally with the tarsus. The tibial diaphysis was round in cross section and resembles an 'S' shaped curve when viewed from the cranial aspect. The entire medial surface was subcutaneous and flat. The caudal surface was ridged for muscular attachment. The lateral surface of tibia was covered by extensor muscles and caudal surface by flexor muscles.

Dyce *et. al.* (1996) stated that blood supply to the tibia was by diaphyseal artery which was a branch of caudal tibial artery. It enters into tibia through the nutrient foramen in the posterio- lateral edge of the proximal one third of the diaphyses. The medial saphenous vein crosses the lateral side of distal tibia. The craniomedial surface of the tibia was not covered by muscles and could be easily palpated to serve as a landmark for location of the incision.

## 2.2 FRACTURE ETIOLOGY AND INCIDENCE

### 2.2.1 Etiology

Aithal *et. al.* (1999) noticed that major cause of fracture was automobile accident (46.86%) followed by fall / jump from a height (39.11%) and miscellaneous causes. They further stated that rickets/osteomalacia was the indirect cause for fracture in 9.45% of cases.

Uma Rani *et. al.* (2004) reported that the major etiological factors causing fractures in dogs were automobile accident (68.24%) and fall from a height (31.76%).

Kushwaha *et. al.* (2011) conducted a study on incidence of fracture and their management in dogs and concluded that fall/ jump (33.37%) was major exciting cause of fractures followed by road traffic accident (23.37%), hit by an object (22.08%) and unknown (20.71%) etiology.

Hari Krishna (2013) stated that the most common cause of fracture was fall from height followed by miscellaneous cause and direct injury to bone in dogs.

Jani *et. al.* (2014) observed that among the causes of fractures road traffic accidents (35.16%) contributed maximum, followed by fall from height (30.77%) and hit injury (20.88%) in dogs.

Ramesh Chandra (2016) concluded that automobile accident (57.14%) was the main etiological factor for fracture incidence in dogs followed by fall from height (28.57%) and unknown etiology (14.29%).

### 2.2.2 Incidence

Thilagar and Balasubramanian (1988) reported that highest incidence of fractures was seen in radius and ulna (31.4%) followed by tibia and fibula (30.4%) and femur (14.7%).

Aithal *et. al.* (1999) concluded that among all long bone, highest number of fractures were seen in femur (38.56%) followed by tibia and fibula (17.16%), radius and ulna (16.92 %) and humerus (7.71%) in a study of 402 clinical cases of dogs.

Dvorak *et. al.* (2000) in a retrospective study comprising 164 long bone fractures in 156 dogs found that radius and ulna were the most commonly fractured bones (28.66%), followed by tibia and fibula (28.05%), femur (25.00%) and humerus (18.29%) among long bones.

Harasen (2003) found that femur bone was fractured most often in the dog and cat (45.0%), followed by tibia (27.0%), radius and ulna (16.0%) and humerus was fractured least often (13.0%).

Kushwaha *et. al.* (2011) observed that fracture incidence was highest in femur (65.0%) followed by radius and  tibia (24.70% each) and humerus (10.0%).

Tambe *et. al.* (2012) evaluated 53 fracture cases in dogs and stated that amongst long bones mid shaft (diaphysial) fractures (64.0%) were more as compared to the proximal third (10.0%) or distal third (18.5%) of fractures. They further stated that occurrence was more in tibia (27.5%), followed by femur (13.5%), radius and ulna (12.50%) and humerus (6.0%).

Hari Krishna (2013) opined that fracture of radius and ulna was more common (35.25%) followed by femur (30.43%), tibia and fibula (27.10%) and least in the humerus (7.22%) and attributed the higher incidence in radius and ulna to less soft tissue coverage.

Jani *et. al.* (2014) stated that among long bones, femur was affected more (55.20%) followed by tibia (17.70%), radius-ulna (10.42%) and humerus (6.25%).

Ramesh Chandra (2016) stated that long bone fractures accounted for 68.63% of total fractures in a study involving 338 cases from Jan 2014 to Nov 2015. He further stated that among long bones, highest incidence was observed in femur (33.92%) followed by radius and ulna (30.86%), tibia and fibula (28.69%) and least in humerus (6.52%).

Singh *et. al.* (2017) stated that incidence of fracture was more in femur (35.71%) followed by radius (20.0%), tibia (16.43%), humerus (8.57 %), metacarpal (5.0%), lumbar vertebra (4.29%), mandible (3.57%), phalanges (3.57%) and metatarsal bones (2.86%).

**2.2.2.1 Breed wise incidence**

Balagopalan *et. al.* (1995) found that fracture incidence was highest in Alsatian breed (27.9 %) followed by Doberman Pinscher (17.8 %), Non-Descript (17.3 %) and Pomeranian (15.4 %) in a retrospective study involving 208 cases of fractures in dogs from 1983 to 1993.

Dvorak *et. al.* (2000) concluded that the most commonly affected breed was Mongrels (21.79%) followed by German Shepherd Dog (5.13%), Yorkshire terrier (3.21%), Dalmatian (3.85%), Staffordshire terrier (3.2%), Fox terrier (1.92%), Miniature pinscher (1.92%), Piccolo levriero italiano (1.28%) and Papillion (1.28%) in a study involving 164 long bone fractures.

Uma Rani *et. al.* (2004) observed that the incidence was highest in Mongrel dogs (54.12%) followed by Pomeranian (12.94%) and other breeds of dogs in a study involving 85 clinical cases of fractures in dogs.

Kushwaha *et. al.* (2011) reported that incidence of fractures was more in Spitz (35.14%) followed by Mongrel dogs (27.03%), German Shepherd Dog (21.62%), Labrador Retriever (5.40%) and other breeds (10.81%).

Jani *et. al.* (2014) found that incidence of fractures was more in Mongrel dogs (32.97%) followed by German Shepherd Dog (25.27%), Spitz (19.78%), Labrador Retriever (14.29%), Pomeranian (3.29%), Boxer (2.20%), Cocker Spaniel (1.10%) and Pug (1.10%).

Ramesh Chandra (2016) observed highest incidence of fractures in Pomeranian (35.89%) followed by Mongrels (34.62%), Labrador Retriever (20.51%), German Shepherd Dog (3.85%), Dachshund (2.56%), Cocker Spaniel and Kanni (1.28% each).

**2.2.2.2 Age and sex wise incidence**

Singh *et. al.* (1983) found higher incidence of fractures in younger animals below one year of age and incidence was higher in male dogs in a study involving 511 clinical cases of fractures in dogs.

Thilagar and Balasubramanian (1988) reported that fractures were more common in pups between 3 to 6 months age (26.6%) and day old to 3 months of age (22.0%).

Balagopalan *et. al.* (1995) stated that fracture incidence was higher in the age group of 3-6 months (30.9%) followed by day old to 3 months (27.9%).

Aithal *et. al.* (1999) concluded that fracture incidence was highest in dogs less than one year (53.65%), followed by 1 to 3 years (35.52 %) and 3 years and above age group (10.83%). They further stated that males (63.16%) were more significantly affected than females (36.84%). Majority of the fractures involved the hind limb (64.57%) followed by forelimb (26.00%).

Dvorak *et. al.* (2000) reported that fracture incidence was more in males (60.9%) than in female dogs (39.1%) and were mostly closed (91.46%) compared to open fractures (8.54%).

Uma Rani *et. al.* (2004) found that fractures were more common in younger animals of less than 1 year of age (58.82%), maximum being between 7-9 month old (22.30%) followed by 4-6 month old (16.47%) in a review of 85 dogs. They further stated that incidence was higher in males (71.71%) than females (28.24%).

Fazili *et. al.* (2005) stated that the prevalence of fractures was more in males (68.0%) than in females (32.0%) in a study involving 100 fractured dogs over 2 years period and attributed it to more aggressive nature of males.

Tambe *et. al.* (2012) observed maximum incidence of fractures in dogs aged between 1 to 3 years.

Jani *et. al.* (2014) stated that occurrence of fractures in male dogs was significantly more (75.83%) than the female dogs (24.17%).

Singh *et. al.* (2017) recorded higher incidence of fracture in male dogs (66.43 %) than the female (33.57%) attributed it to higher population of male or males were preferred more as companion pet than the female in the area of study. They further stated that dogs less than one year of age (54.29%) were affected more than above one year (45.71 %).

## 2.3 CLINICAL SIGNS

Johnson *et. al.* (1998b) observed clinical signs such as non-weight bearing, limb swelling, pain, crepitus, abnormal posture or limb positioning or abnormal mobility of the hock joint and reluctance to move the limb in femoral diaphyseal fractures in dogs.

Roush and McLaughlin (1998) stated that dogs with fracture would often present limb dysfunction, pain, fracture instability, overlying soft tissue trauma, abnormal posture or limb position and crepitus.

Piermattei *et. al.* (2006) concluded that before the most appropriate method for treating a problem could be selected, the orthopaedic problem must be identified and assessed. They further stated that in cases of fractures of long bones, symptoms like swelling, dangling of the limb, non-weight bearing, abnormal angulation of the limb at the fracture site and crepitation were generally apparent.

## 2.4 DIAGNOSIS AND CLASSIFICATION OF FRACTURES

### 2.4.1 Diagnosis

Roush and McLaughlin (1998) found that radiographic examination of at least two divergent views of the affected bone, preferably at 90 degrees to one another were necessary to accurately assess the fracture configuration.

Kraus *et. al.* (2003) opined that high quality radiographs were essential for placement of plates and for the detection of fissures that might propagate during reduction and plate placement so that they could be avoided.

Langley-Hobbs (2003) stated that atleast two radiographic views including joints above and below the fracture were required for radiographic diagnosis and the radiographic signs include a break in the continuity of the bone, a line of radiolucency when fragments are compressed or superimposed.

Kealy and McAllister (2004) recommended at least two radiographic views at right angle to one another for proper evaluation of the status of a bone. Standard views for limb bones are cranio-caudal and medio-lateral.

Shales (2008) stated that the fracture should be radiographed, with two orthogonal views of the affected limb taken as a minimum. He further stated that the quality of the images should be good enough to spot potential fissures that could extend into major fragments and significantly complicate the repair.

Ramesh Chandra (2016) expressed that lateral and cranio- caudal radiographic views were satisfactory in providing confirmatory diagnosis and classification of long bone fractures.

### 2.4.2 Classification of fractures

Unger *et. al.* (1990) classified long bone fractures in dogs and cats by giving an alpha numeric code with four digits, representing the fracture description in a defined order, in which the first two digits represented the localization of the fracture and the last two digits its morphology. The first symbol of the alpha-numeric code represented the fractured bone: 1. Humerus, 2. Radius/ulna 3. Femur, 4. Tibia/fibula. The second symbol represented the segment of long bone in which the fracture was centered: 1. Proximal, 2. Diaphyseal, 3. Distal. Based on morphological characteristics each fracture was coded into 3 types A. B, C and each into 3 groups ($A_{1,}$ $A_{2,}$…….$C_3$). They further stated that most common fracture sites were located in the diaphysis (60.0% of all cases). Diaphyseal fractures were more frequent in radius/ulna (75.0%) and tibia/fibula (72.0%) as compared with femur (50.0%) and humerus (47.0%).

Balagopalan *et. al.* (1995) reported high incidence of oblique fractures than transverse fractures in tibia in dogs.

Newton and Nunamaker (1995) reported more incidence of oblique or spiral fractures than any other type in dogs suggestive of predominant action of bending or compressive force on the bone.

Miller *et. al.* (1998) described AO/ASIF fracture classification system of long bone fracture using alphanumeric code to identify location and morphology. This system provided a complete description of fracture morphology and was found to be more easily adaptable for cats and dogs. The first digit identifies the bone (1 – humerus, 2 – radius-ulna, 3- femur, 4– tibia- fibula). The second digit identifies the location of fracture in the bone (1- proximal, 2- diaphyseal, 3- metaphyseal). The fracture morphology was described using letters A, B and C as A- simple, B- Wedge fractures and C- complex fracture.

Singh *et. al.* (1999) recorded more incidence of transverse fracture (40.0%) followed by overriding (30.0%), oblique (23.3%) and distracted (1.0%).

Denny and Butterworth (2000) classified fractures according to anatomical location, external wounds, extent of bone damage, direction of fracture line, relative displacement of fracture line, stability. They further classified fractures based on stability into oblique, spiral or comminuted fractures, in which the fragments do not interlock and a method of fixation was needed to maintain the length of the bone and prevent angular deformities and rotation. This usually involves application of a plate and screws or external fixators.

Uma Rani *et. al.* (2004) reported that among femur fractures, transverse fractures (45.88%) were most common followed by oblique fracture (42.35%) and most of femur fractures were overriding in nature (79.17 %).

Kushwaha *et. al.* (2011) observed that 60.0% were transverse fractures followed by oblique (35.0%) and comminuted fractures (5.0%) fractures.

Hari Krishna (2013) opined that all the fractures were closed and unstable in a study involving 75 cases and the fracture were either transverse or oblique.

Rhangani (2014) noticed that the most common type of fracture encountered was complete simple transverse fracture (65.0%), followed by oblique (15.0%) and comminuted (5.0%) fractures.

## 2.5 BIOLOGICAL OSTEOSYNTHESIS AND ELASTIC PLATE OSTEOSYNTHESIS

Sturmer (1996) described Elastic Plate Osteosynthesis as a biological method which was safer and superior to the rigid technique even applied to short oblique and transverse fractures. Elasticity was achieved by leaving a flexible stretch of at least 2-4 plate holes i.e., as long as possible without screws over the fracture and this would allow micro movement at the fracture site.

Johnson *et. al.* (1998a) reported that biological fixation of comminuted fractures was associated with increased callus production, accelerated radiographic union, earlier gain in biomechanical strength and therefore, earlier return to function when compared to stable fracture fixation.

Cabassu (2001) observed that two proximal and distal cortical screws placement on plate as far as possible from the fracture line increased the elasticity of the plate between the screws during femoral fracture repair by Elastic Plate Osteosynthesis using VCP in 24 young growing dogs. The plate was applied following bridge plating principles. He further stated that it resulted in rapid formation of periosteal callus due to micromotion of the bone fragments.

Sarrau *et. al.* (2007) opined that the use of long thin plates such as Veterinary Cuttable Plates of 2.0 -2.7 mm in young dogs with two screws in the proximal and the distal fragments as far as possible from the fracture site would limit traumatic lesions of the growth plates and tearing forces on screws by increasing the elasticity of the plate between the screws. Implant would allow rapid formation of periosteal callus due to micromotion of bone fragments.

Dejardin and Cabassu (2008) stated that the application of Veterinary Cuttable Plate (VCP) for femoral shaft fractures in young dogs according to bridge plating principles i.e., using longer plate and fewer screws was helpful in promoting rapid bone healing. They further stated that the screw positioning (two adjacent screws should always be oriented in diverging planes) and distribution decreased the stress riser effect of a single empty screw hole and therefore reduced bone/screw interface stresses, which limited the risk of implant failure via screw pullout. The screw distribution increased the overall compliance of the repaired bone- plate construct.

Gautier (2009) observed that the pullout force acting on the screw decreased as the working length of the plate was increased. He further stated that the plate screw density maintained to a maximum value of 0.5 and the distance between the innermost screws should be increased from fracture site, leaving at least two to three plate holes unoccupied at the fracture site to decrease the plate loading which in turn avoids fatigue failure in bridge plating technique.

Heo *et. al.* (2012) mentioned that the surgery was successful and the fractures healed without any complications by 7 weeks (case 1), 10 weeks (case 2) and 8 weeks (case 3) after surgery and patients showed fast bone healing and early weight bearing after MIPO with VCP.

## 2.6 FRACTURE REPAIR IN YOUNG DOGS

McLain and Brown (1982) suggested a variety of methods to treat radius and ulna fractures in growing animals: external splints or casts, intramedullary pins, pins combined with splints, crossed pins, external skeletal fixation devices, plates and screws, and plates supplemented by splints.

Bruse *et. al.* (1989) used Veterinary Cuttable Plates for internal fixation for fracture repair in small animals.

Larsen *et. al.* (1999) opined that plate fixation provides a successful method of repair for distal radius and ulna fractures in small- and miniature-breed dogs.

Peirone *et. al.* (2002) treated femoral and humeral fractures with intramedullary pin\external fixator tie-in technique in young growing dogs and cats.

Reems *et. al.* (2003) suggested that plate-rod constructs could successfully be used for repair of diaphyseal fractures of a wide range of severity in dogs and cats.

Milovancev and Ralphs (2004) opined that application of bone plate and screws for radial fractures was an adaptable and very stable method of fixation allowing for immediate weight bearing.

Ramirez and Macias (2016) stated that conventional bone plating for repair of distal radius and ulna fractures in toy breed dogs resulted in excellent functional outcome in cases with no previous surgical intervention.

## 2.7 PREOPERATIVE PREPARATION

### 2.7.1 Patient preparation

Lidwell (1982) opined that reduction in post-operative infection rates as low as 5% or lower in clean orthopaedic procedures was achieved by the administration of prophylactic antibiotics.

Penwick (1985) stated that factors such as positioning of the animal on the operating table, preoperative skin preparation and draping techniques may contribute markedly to the comfort and convenience of the patient as well as to the incidence of postoperative wound infection.

Gupta (2005) withheld food and water for 12 hours prior to surgery and the site was prepared for surgery by clipping and shaving hair during repair of humeral and tibial shaft fractures using interlocking nails under c-arm image intensifier.

Dwivedi *et. al.* (2009) withheld food for 24 hours and water for 6 hours prior to anaesthesia.

Bhatia (2010) recommended 12 hours off-feeding and 6 hours with holding of water prior to anaesthetic induction. All the animals were given preoperative antibiotic amoxicillin clavulanate at the rate of 20 mg per kg body weight, i.m. 30 minutes before induction of anaesthesia.

Das *et. al.* (2012) withheld food for 12 hours prior to surgery and water was provided until 4 hours prior to premedication in dogs during orthopaedic surgery.

### 2.7.2 Anaesthesia

Hellyer *et. al.* (1991) stated that induction was reported to be smooth and free from excitement with ketamine-midazolam combination in dogs.

Thurmon *et. al.* (1996) stated that atropine was an anticholinergic (parasympathetic) drug frequently used to reduce the secretion in the respiratory tract and salivary glands and also to inhibit the vagal stimulation of the cardiovascular and respiratory system.

Ranpariya *et. al.* (2013) concluded that the use of butorphanol-acepromazine glycopyrrolate given 15 minutes prior to induction of general anaesthesia was an effective premedicant combination in dog orthopaedic surgeries. This combination neutralized the side effects of individual agents and provided excellent analgesia, sedation and anti sialogogue effects. They further stated that induction with midazolam-ketamine and maintenance with isoflurane anaesthesia provided stable maintenance for orthopaedic procedures.

Nithin (2016) observed that butorphanol-acepromazine-atropine and tramadol-acepromazine-atropine premedication provided good sedation in clinical orthopaedic surgeries in dogs induced with ketamine-diazepam and maintained with isofluorane. He further stated that the quality of sedation and induction were better in butorphanol group with better anaesthetic sparing effect.

## 2.8 SURGICAL PROCEDURE

### 2.8.1 Patient position

McCartney *et. al.* (2010) suggested that dog can be placed in dorsal recumbency in a trough, with the leg under traction caudally at an angle of approximately 60 degrees to the table top during repair of radial/ulnar fractures in 17 toy breed dogs.

Peirone *et. al.* (2012) recommended lateral recumbency with the affected limb lowermost and the contralateral hindlimb secured caudally with the stifle flexed and the hip extended for the application of medial plate for tibial diaphysial fracture.

### 2.8.2 Surgical approach

Vaughan (1963) recommended antero-lateral approach for radius fracture repair. The exposure of the radius involved separation of the extensor tendons which had become enveloped in the mass of fibrous tissue that circumscribed the fracture.

Piermattei (1993) stated that medial incision starting from proximally over the medial tibial condyle and curves cranially to the midline of the tibia at midshaft, curves caudally to the end near medial malleolus could be used for medial application of plate in tibial fractures.

Piermattei and Johnson (2004) opined that the commonly used approach to the radial diaphysis was cranio-medial as it exposes the radius shaft. They further stated that for fractures from proximal to middle portion of the diaphysis, a lateral approach between the extensor carpi radialis and common digital extensor muscles was preferred. For distal diaphyseal fractures, a cranial (dorsal) approach was frequently chosen.

Pozzi and Lewis (2009) advocated a cranio-medial approach to the radius which was a combination and modification of the approaches to the diaphysis of the radius through a medial incision and the distal aspect of the radius and carpus through a dorsal incision. They further advocated a medial approach to the tibia which was a combination and modification of the approaches to the proximal tibia through a medial incision and to the shaft of the tibia placing the dog in dorsal recumbency.

Pozzi *et. al.* (2013) advocated dorsomedial or dorsolateral approaches with the dog positioned in lateral recumbency and the fractured limb nondependent during ORIF of radius and ulna fractures with or without bone grafting according to surgeon preference.

Minto *et. al.* (2015) stated that a craniomedial approach was used in radius and the periosteum was elevated only enough to fit the plate directly on the bone. A ten-hole 2.7 Locking Compression Plate was contoured and applied to the cranial aspect of the radius.

Ramirez and Macias (2016) employed a standard lateral approach to the distal radius, with a slightly more cranial skin incision for stabilisation of distal diaphyseal fractures of the radius in the toy breed dogs using DCP or VCP with 2.0mm screws.

### 2.8.3 Surgical technique

Larsen *et. al.* (1999) suggested bone plate fixation method for distal radius and ulna fracture repair in small- and miniature-breed dogs.

Reems *et. al.* (2003) suggested that plate-rod construct can successfully be used for repair of diaphyseal fractures of a wide range of severity in dogs and cats.

Milovancev and Ralphs (2004) repaired radius/ulna fractures with application of bone plates and screws.

McCartney *et. al.* (2010) stabilised distal radial fractures with mini plates or VCP or external fixator with cancellous bone graft.

Piras *et. al.* (2011) treated the fractures of the distal radius and ulna in toy breeds with circular external skeletal fixator and concluded that the technique provides an alternative to other methods of fracture fixation.

Ramirez and Macias (2016) opined that conventional bone plates were suitable choices for stabilisation of distal radius and ulna fractures in toy breed dogs. All screws distal to the fracture site were applied first without reducing the fracture, ensuring the plate was positioned centrally in relation to the long axis of the radius. The proximal fragment was reduced and the remaining screws applied once reduction and plate alignment were considered adequate.

**2.8.3.1 Veterinary Cuttable Plate (VCP)**

Bruse *et. al.* (1989) described the use of two sizes of Veterinary Cuttable Plates for fracture repair of long bones in 42 cats and small dogs, distal limb bones, mandible and pelvis in middle sized and large dogs. They stated that the length of VCP was fitted to the broken bone by cutting and stiffness could be increased by sandwiching two plates together. They further stated that plate should always be used in sandwich fashion when the fracture was comminuted, otherwise the plate might break or bend.

Fruchter and Holmberg (1991) concluded that the cuttable plates were more resistant to a bending force than mini bone plates accepting 1.5 mm and 2.0 mm bone screws and less resistant than the 2.7 mm dynamic compression plate. They further stated that the stiffness of two stacked VCPs was approximately equal to the sum of the stiffness of each plate but were less rigid than 2.7 mm DCP.

McLaughlin *et. al.* (1992) repaired comminuted long bone fractures in four cats using stacked 2.0 or 2.7 mm Veterinary Cuttable Plates as lengthening plates, spanning the cortical defects to maintain limb length and the defects were filled with autogenous cancellous bone graft. The authors observed that the plates did not break through unfilled screw holes and good to excellent limb function was noticed in all cases.

Gentry *et. al.* (1993) stated that VCP was small and thinner and has more holes per unit length than a DCP. They further stated that its relative low cost was also advantageous.

Hammel *et. al.* (2006) evaluated fatigue life of stacked and single Veterinary Cuttable Plates in an invitro biomechanical comparative study. They concluded that the stacked VCP constructs have greater fatigue lives than single VCP and LC-DCP constructs. Plates with 2.4 mm screws were not significantly different from comparable construct with 2.0 mm screws.

Dejardin and Cabassu (2008) described Elastic Plate Osteosynthesis (EPO) technique of application of VCP with minimal invasive approach on femoral shaft fractures in young dogs which reduced bone/screw interface stresses and further risk of implant failure via screw pullout. They further stated that rapid bone healing via callus formation was seen in this technique avoiding the chance of occurrence of fracture disease when compared to other techniques. The screws were applied avoiding central plate span as long as possible and include not less than 3 consecutive empty screw holes. This decreases the stress riser effect of a single empty screw hole, thus reducing the risk of implant fatigue failure.

Zahn *et. al.* (2008) tested mechanical properties of 18 different AO bone plates and the Clamp Rod Internal Fixation (CRIF) system on a canine gap model construct. The authors found that the sectional geometry of the VCP probably generated a moderately higher bending stiffness and strength compared to the DCP and the CRIF within the 2.0 mm group, but weaker in stiffness than the DCP in 2.7 mm group.

Gautier (2009) opined that the distance between the innermost screws should be increased from fracture site, leaving at least two to three plate holes unoccupied at the fracture site to achieve plate stability by decreasing the plate loading to avoid fatigue failure in bridge plating technique and he found that the pullout force acting on the screw decreased as the working length of the plate had increased with the plate screw density maintained to a maximum value of 0.5.

Guiot and Dejardin (2011) concluded that the VCP was the most compliant construct useful in juvenile dogs and cats because of its thinness, high hole density and flexible fixation in promoting bone healing than DCP and LC-DCP during prospective evaluation of Minimally Invasive Plate Osteosynthesis in 36 nonarticular tibial fractures in dogs and cats using LCP, LC-DCP, VCP bone plates with or without intra medullary pin.

### 2.8.4 Implants used

Bruse *et. al.* (1989) stabilised fractures with either single 2.0/2.7mm VCP plates or sandwiching two plates of either type in cats and in dogs.

McLaughlin *et. al.* (1992) used stacked 2.0/2.7mm Veterinary Cuttable Plates for repair of comminuted diaphyseal fracture repair in cats.

Sarrau *et. al.* (2007) employed either 1.5/2.0mm or 2.0/2.7mm VCP and 2.0mm or 2.7mm cortical screws respectively or a straight plate with 2.0mm screws for stabilising femur diaphyseal fractures in medium or large breed puppies less than four months old and tibial diaphyseal fractures were stabilised with VCP using 2.0/2.7mm screws. Two or three cortical screws were implanted without tapping the thread in each bone fragment as far as possible from the fracture site.

### 2.8.5 Plate length

Cabassu (2001) stated that the plates were cut to the desired length, according to the anticipated position of the screws during femoral fracture repair by Elastic Plate Osteosynthesis using VCP in 24 young growing dogs The screws were placed in the two most proximal and two most distal screw holes of the plates.

Dejardin and Cabassu (2008) stated that restoration of the femoral length was achieved by determining the appropriate plate length from cranio-caudal radiographic views of the contralateral intact femur and the plate was cut to the desired length according to the anticipated position of the screws in relation to the growth plates. The screws were placed in the two most proximal and the two most distal screw holes of the plate.

Gautier (2009) found that the plate length should be two to three times higher than the overall fracture length in comminuted fractures and eight to ten times higher in simple fractures. He further stated that two screws on each main fragment was the minimum number of screws needed to keep the plate-bone construction stable.

Heo *et. al.* (2012) repaired tibial diaphyseal fractures by minimally invasive plate osteosynthesis using VCP. They cut and contoured 2.0mm VCP preoperatively based on contralateral radiographs of the normal tibia.

**2.8.6 Surgical time**

Johnson *et. al.* (1998b) reported a mean surgery time of 116 minutes for open-bridge plating and 191 minutes for plating with fragment reconstruction of comminuted femoral fracture in dogs.

Pozzi *et. al.* (2013) recorded a mean time of 103.2±40.3 minutes for performing surgery by MIPO and 113.5±37.9 minutes for ORIF in a comparative study during radius and ulna fracture stabilisation in dogs.

Daniella (2017) stated that the mean time taken for surgery was 54 minutes for radius and tibia fracture stabilisation by MIPO in dogs.

### 2.8.7 Post-operative care

Tobias (1995) stated that Robert Jones bandage was indicated for injuries distal to elbow and it provided more stability than a padded bandage because of its added thickness; however, its extremely bulky size makes it unwieldy and restricted ambulation. Major advantages of Robert Jones bandage included its increased stability over padded bandages and its tremendous absorbent capacity.

Denny and Butterworth (2000) reported that Robert Jones bandage can be used 5 to 10 days post-operatively to provide additional support and to control oedema.

Mohindroo *et. al.* (2006) reported that Robert Jones bandage provided an excellent adjunct to support the internal fixation technique applied, by further stabilising the fractured fragments.

Sarrau *et. al.* (2007) advocated the use of a small bandage on surgical wound after ORIF of femur and tibia fractures with VCP in 2-4 months old puppies.

Schmokel *et. al.* (2007) recommended applying a modified Robert-Jones bandage for several days and limiting exercise to indoor confinement with leash walks for 6-10 weeks in dogs that have had fractures stabilized using the MIPO technique.

### 2.8.8 Complications

#### 2.8.8.1 Intraoperative complications

Tan and Balogh (2009) observed that the locking plates used in the offset position from the periosteal surface might cause tendon and soft tissue irritation, if the plate was too prominent.

### 2.8.8.2 Postoperative complications

Larsen *et. al.* (1999) explained that inherent biomechanical instability of radius, decreased intraosseous blood supply and limited overlying soft tissue for provision of an extra osseous circulation would contribute to higher frequency of delayed union and non-union fractures in small- and miniature-breed dogs.

Rahal *et. al.* (2003) reported implant associated osteomyelitis in a dog. They further stated that infection, fistula, inflammatory reaction and hypersensitivity were among the other complications related to implants.

Sarrau *et. al.* (2007) recorded one implant failure i.e, plate bending in a 4-month old Beauceron Sheepdog puppy among 17 puppies treated by EPO with VCP.

Theoret and Moens (2007) observed screw loosening in a case and treated with screw removal and antibiotics.

Das *et. al.* (2012) observed seroma formation at distal tibia, self-mutilated wound, mild and severe plate bending and screw loosening with exposure through the skin as the potential complications after treatment of diaphyseal fractures of tibia with DCP.

### 2.8.9 Implant removal

Piras (2000) stated that plate removal was essential usually after 3 to 5 weeks to avoid plate entrapment by appositional bone growth and to avoid stress protection during the intense physical activity.

Sarrau *et. al.* (2007) advocated plate removal 4-8 weeks after surgery, as soon as radiographic evidence of bone healing was observed during treatment of femoral and tibial fractures in 2-4 months old puppies by EPO using VCP. They further stated that plate removal was delayed upto 10-16 weeks after surgery in some cases.

Johnson (2013) recommended plate removal when the plates have been applied in areas with limited soft tissue covering, such as radius and tibia because cold conduction might cause discomfort and recommended plate removal in younger patients also. He further stated that plate removal had to be performed aseptically with the patient under general anaesthesia.

## 2.9 EVALUATION OF FRACTURE HEALING

### 2.9.1 Clinical evaluation

McLaughlin *et. al.* (1992) observed minimal weight bearing on the operated limbs within four days of surgery and using the limb well within three weeks after stabilisation of comminuted diaphyseal fractures by stacking of Veterinary Cuttable Plates in cats.

Cabassu (2001) noted most of the dogs began to use their leg before returning home during femoral shaft fracture repair in young dogs by Elastic Plate Osteosynthesis.

Sarrau *et. al.* (2007) found that all puppies started using their repaired limb soon after surgery during treatment of femur and tibia diaphyseal fractures by EPO with VCP in young puppies.

Gomaa *et. al.* (2016) stated that 3 dogs showed ability to walk and jump after one month following metacarpal fracture with VCP in 5 mongrel dogs.

Rao *et. al.* (2017) observed partial weight bearing from $3^{rd}$ – $7^{th}$ post-operative day, moderate limb usage was observed from $7^{th}$ – $15^{th}$ post-operative day and complete weight bearing was noticed from $32^{nd}$ day onwards after treating the radius-ulna and tibial diaphyseal fractures with type IIa external skeletal fixator.

**2.9.2 Radiographic evaluation**

Sturmer (1996) observed spontaneous healing via fixating callus formation within first 3-6 weeks out of periost-soft tissue combination after Elastic Plate osteosynthesis. He stated that no delayed bone healing, pseudoarthrosis or bone infection was observed in Elastic Plate Osteosynthesis technique despite the presence of soft tissue damage.

Cabassu (2001) observed partial callus formation two weeks post-operatively and was often complete by four weeks during femoral fracture repair by Elastic Plate Osteosynthesis using VCP in 24 young growing dogs. Initially, the callus appeared on the medial, cranial and caudal sides of the bone and finally on the lateral side. Remodelling of the callus was observed after two months and appeared to be advanced by four months, when corticalisation was also obvious.

Sarrau *et. al.* (2007) opined that cranio-caudal and medio-lateral radiographic views were useful to observe overall outcome of fracture healing and any femoral retroversion after Elastic Plate Osteosynthesis with Veterinary Cuttable Plates for the treatment of femur and tibia diaphyseal fractures. They further stated that bone healing was noticed between 4 to 8 weeks postsurgery in all the cases.

Dejardin and Cabassu (2008) found clinical union as early as two weeks and was achieved in all the cases by four weeks post-operatively. They further stated that remodelling of the callus was observed after two months and bony union by 4 months.

### 2.9.3 Lameness grading

McLaughlin *et. al.* (1992) observed minimal weight bearing on the operated limbs within four days after surgery and using the limbs well within three weeks after repair of comminuted diaphyseal fractures with stacked Veterinary Cuttable Plates in cats.

Dymond *et. al.* (2010) assigned a lameness grade to all the cases during pre and post treatment period based on the weight bearing nature during stance and while walking as follows

Grade 0 - No lameness

Grade 1 - Mild lameness – occasional gait abnormality.

Grade 2 – Moderate lameness – obvious gait abnormalities,

Grade 3 - Moderate lameness – obvious gait abnormality and occasional non-weight bearing

Grade 4 – Severe lameness – Consistently non – weight bearing.

### 2.9.4 Functional limb outcome

Clark (1986) conducted periodical clinical examinations during postoperative period to assess the functional limb outcome and categorized the animals as excellent, good, fair and poor in all the groups of animals as follows:

Excellent : No lameness, no more than 15° loss of range of motion compared to the dog's opposite limb, no post-operative complications

Good : Moderate occasional lameness, does not require treatment, 20° to 30° loss of range of motion, no postoperative complications

Fair : Moderate persistent lameness requiring treatment, 40° to 60° loss of range of motion

Poor : Persistent severe lameness with loss of greater than 40° range of motion.

McLaughlin *et. al.* (1992) observed excellent limb function in three cats and good limb function in one during treatment of comminuted diaphyseal femur and humerus fractures with VCP in cats.

Cabassu (2001) noticed 'very good' functional limb outcome in 21 out of the 22 dogs during femoral fracture repair by Elastic Plate Osteosynthesis using VCP in 24 young growing dogs after gait evaluation. One dog exhibited slight lameness which was attributed to stifle problems.

Sarrau *et. al.* (2007) found excellent clinical outcome during treatment of femoral and tibial diaphyseal fractures by Elastic Plate Osteosynthesis with Veterinary Cuttable Plates in 17 medium and large breed puppies less than four months old.

Theoret and Moens (2007) opined that VCP provided good clinical outcome as good as other types of implants and it was an implant of choice for pancarpal, partial tarsal and pantarsal arthrodesis.

## 2.10 SERUM BIOCHEMISTRY

### 2.10.1 Serum calcium

Bush (1991) reported that serum calcium levels increased slightly on 5th postoperative day and later increased significantly reaching peak level on the 15th postoperative day followed by gradual decline to near base value on 60th postoperative day but it remained above the normal value following fracture repair in dogs. He further stated that the gradual decline in serum calcium level from 30th postoperative day might be due to more rapid calcification at fracture site.

Nagaraja *et. al.* (2003) studied serum biochemical variations following immobilization of experimentally created midshaft femur osteotomies in dog, before and on postoperative days 1, 2, 3, 7, 9, 11, 13, 15, 60 and 90. The levels of serum calcium increased gradually up to 15th postoperative day and rapidly thereafter which was statistically insignificant and the increase in calcium level could be attributed to mineralization process at the osteotomy site.

Julie (2005) observed significant decrease in the serum calcium levels by fourth week post-operatively, which remained same during the sixth week in dogs with radial and tibial fractures treated with external skeletal fixators.

Daniella (2017) found no statistically significant difference in the serum calcium and phosphorous values at different time intervals post-surgery in dogs after MIPO and the values were within the normal range.

Kumar *et. al.* (2018) observed that the serum calcium mean values showed a significant rise up to 14 days post-surgery followed by gradual decrease reaching base value at 60$^{th}$ postoperative day. The serum calcium level in all the animals fluctuated within normal physiological range. This could be due to severe trauma with comminuted and unstable fractures.

**2.10.2 Serum phosphorus**

Siemens (1970) reported that serum inorganic phosphorus level elevated immediately after fracture fixation and significantly increased level was recorded on the 30$^{th}$ postoperative day and thereafter decreased to reach normal level on 60$^{th}$ postoperative day.

Nagaraja *et. al.* (2003) recorded gradual increase in phosphorus level up to 15$^{th}$ post-operative day and rapidly thereafter which was statistically insignificant. The increase in phosphorus could be due to necrotic disintegration of cells at the fracture site.

Julie (2005) observed significant decrease in the serum phosphorus levels during fourth and sixth week post-operatively in dogs with radial and tibial fractures treated with external skeletal fixators.

Uma Rani *et. al.* (2012) observed significant increase in serum inorganic phosphorous level on 3rd post-operative day and there after the values were significantly reduced and reached near base value on 60$^{th}$ postoperative day. They further opined the early rise in serum phosphorous level could be due to the necrotic disintegration of the cells at the site of fracture.

Kumar *et. al.* (2018) observed no significant variation in the serum phosphorous mean values postoperatively and the values were within the normal range.

### 2.10.3 Serum alkaline phosphatase

Guyton (1981) reported an increase in alkaline phosphatase level in most of the compression methods of internal fixation and attributed the same to increased osteoblastic activity.

Maiti *et. al.* (1999) recorded an increase in serum alkaline phosphatase level from $5^{th}$ postoperative day, reached peak level at the $15^{th}$ postoperative day and thereafter a declining trend was followed up to the $60^{th}$ postoperative day and remained above the base line values. They further stated that this increased alkaline phosphatase activity might be an indication of increased chondroblastic proliferation to cause bone formation during fracture repair.

Chandy (2000) stated that serum alkaline phosphatase level showed a significant increase from the pre-operative day to $28^{th}$ post-operative day.

Nagaraja *et. al.* (2003) observed no significant variation in the postoperative plasma alkaline phosphatase value from that of preoperative day values, however, values declined from $30^{th}$ postoperative day onwards.

Julie (2005) observed a significant increase in the alkaline phosphatase level by second week and significant decrease by fourth week in dogs with radial and tibial fractures treated with external skeletal fixators.

Hegade *et. al.* (2007) reported a significant increase in serum alkaline phosphatase on the day of surgery during fracture immobilization and was attributed to proliferation of osteogenic cells with maximum contribution from the periosteum of destructed bone, which was a rich source of serum alkaline phosphatase.

Mahendra *et. al.* (2007) observed significant increase in serum alkaline phosphatase levels throughout the study period, which might be due to the process of increased osteogenic activity and deposition of calcium salts at the site of fracture.

Phaneendra *et. al.* (2016) concluded that serum alkaline phosphatase values significantly increased from preoperative day to $14^{th}$ day and there after the levels decreased reaching base value by $21^{st}$ postoperative day. They stated that the increased level was due to increased chondroblastic proliferation to cause bone formation during bone repair and also maximum contribution was from the periosteum of destructed bone which was a rich source of serum alkaline phosphatase.

Daniella (2017) noticed a non-significant decrease in the serum alkaline phosphatase levels, from the initial base value till the end of the $2^{nd}$ month of post-surgery.

Patil *et. al.* (2017) observed no significant variation in the serum alkaline phosphatase values while studying physiological and haemato-biochemical changes during repair of femur fracture in dogs.

Kumar *et. al.* (2018) observed that the serum alkaline phosphatase values significantly increased from preoperative day to $14^{th}$ postoperative day and there after the level decreased reaching normal by $60^{th}$ postoperative day. They further stated that increase in serum alkaline phosphatase level might be due to increased chondroblastic proliferation to cause bone formation during fractured bone repair and also maximum contribution was from the periosteum of destructed bone which was a rich source of serum alkaline phosphatase.

# Chapter -III

# MATERIALS AND METHODS

## 3.1 SELECTION OF CASES

Dogs below one year age presented with a history of forelimb or hindlimb lameness, suggestive of either radius or tibia fracture, to the Department of Veterinary Surgery and Radiology, NTR College of Veterinary Science, Gannavaram from June 2017 to May 2018 were considered for the study.

## 3.2 DESIGN OF STUDY

Six young dogs aged below one year with unstable radius or tibia fracture were selected to study the fracture stabilisation by Elastic Plate Osteosynthesis technique using 2.0/2.7 mm Veterinary Cuttable Plate. (Table. 1).

**Table. 1 Details of the cases treated with VC Plating in dogs**

| Case no. | Breed | Age (months) | Sex | Weight (kg) | Limb involved | Etiology | Bone involved | Type of fracture |
|---|---|---|---|---|---|---|---|---|
| 1. | Spitz | 3 | F | 3.4 | L | Automobile accident | Tibia | Complete, transverse, overriding proximal 3rd fracture of left tibia and fibula |
| 2. | German Shepherd Dog | 8 | F | 16.5 | R | Automobile accident | Radius | Comminuted, slight overriding distal 3rd fracture of right radius and ulna with a fissure extending upto proximal third |
| 3. | Mongrel | 4 | F | 7.2 | R | Fallen from height | Tibia | Complete, oblique, proximal 3rd, slightly displaced right tibiofibular fracture |
| 4. | Mongrel | 6 | F | 6.8 | R | Fallen from height | Radius | Comminuted, slight overriding distal 3rd fracture of right radius and ulna |
| 5. | Pomeranian | 7 | F | 5.9 | L | Fallen from height | Tibia | Complete, midshaft, long oblique, over riding tibio fibular fracture |
| 6. | Labrador Retriever | 6 | M | 19.6 | L | Fallen from height | Tibia | Complete, midshaft, spiral, unstable tibio-fibular fracture |

M-Male F-Female L-Left R-Right

## 3.3 INCIDENCE

Incidence of long bone fractures in young dogs among the total number of fractures presented was studied. Breed, age, sex and body weight of the animals were recorded and analysed.

## 3.4 ETIOLOGY

A detailed history about etiology of fracture was obtained from the owners and recorded.

## 3.5 CLINICAL, ORTHOPAEDIC AND RADIOLOGICAL EXAMINATION

Detailed clinical, orthopaedic and radiological examination was carried out for diagnosis. Lateral and cranio-caudal radiographs of the fractured bone were taken at 90 degrees angle (Shales, 2008) for confirmatory diagnosis, classification of fractures, selection of implants and approach.

## 3. 6 CLASSIFICATION OF FRACTURES

After confirming diagnosis, the fractures were classified based on bone, area involved and fracture configuration in all the animals using AO classification. According to area involved and fracture configuration, fractures were classified as transverse, comminuted, oblique and spiral (Newton and Nunamaker, 1995).

According to AO classification each fracture was described using alpha numeric code which designated the bone involved, fracture location, fracture morphology and its severity. In this code, the first digit identifies the bone (1- Humerus, 2- Radius-Ulna, 3-

Femur, 4- Tibia-Fibula). The second digit identifies the location of the fracture in the bone (1- Proximal, 2- Diaphyseal, 3- Distal).

The fracture morphology was described using a letter A, B, C as A-simple, B-wedge fractures, and C-complex fractures. Each grade was further grouped into three degrees of complexity with increasing severity (viz., C1, C2, C3) depending upon the type and extent of bone fragmentation. The code used for the fracture morphology and its complexity of the distal and proximal extra-articular fractures was different from that of diaphyseal fractures (Miller *et. al*. 1998).

## 3.7 INSTRUMENTATION AND IMPLANTS

### 3.7.1 Instrumentation

A standard orthopaedic set (Fig. 1) and a general surgical instrumentation set were used in the study.

Special orthopaedic instruments (Fig. 2) used for VCP application were as follows:

1. Drill guide 2.0 mm
2. Drill bit 1.5 mm/2.0 mm
3. Hexagonal screw driver 2.0 mm/2.7 mm

### 3.7.2 Implants used

Indigenously made Veterinary Cuttable Plates (VCP) were used for stabilization of fractures (Advance Orthotech, Chennai) (Fig. 3).


Fig. 1 Photograph showing standard orthopaedic set

1 – Senn Retractor

2 –Serrated Bone Holding Forceps

3 – Periosteal Elevator

4 –Self Centering Bone Holding Forceps

5 - Bone Cutter

6 – Pin Cutter

7 –Electric Power Drill

8 – Key


Fig. 2 Photograph showing special orthopaedic instruments

1. Drill guide 2.0 mm
2. Drill bit 1.5 mm/2.0 mm
3. Hexagonal screw driver 2.0 mm/2.7 mm

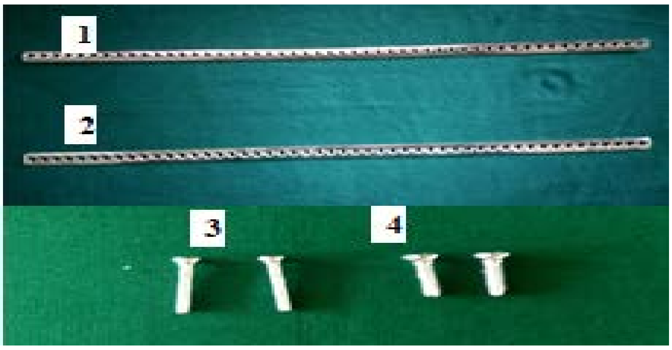


Fig. 3 Photograph showing implants used

1. 2.0 mm Veterinary Cuttable Plate

2. 2.7 mm Veterinary Cuttable Plate

3. 2.0 mm Self-tapping Screws

4. 2.7 mm Self-tapping Screws

Veterinary Cuttable Plates were used for internal fixation of long bone fractures in small dogs and cats and for small bone fractures in large breeds. They come in 2 sizes, both with a width of 7.0 mm and in a 50-hole length measuring 300 mm. VCP in two sizes, 2.0 mm and 2.7 mm, were used having the common measurements with width of 7.0 mm and 50-hole length measuring 300 mm with the hole to hole distance of 6.0 mm. Only thickness and hole measurements vary according to size of screw. The smaller plate (1.5/2.0) has a thickness of 1.0 mm, a plate hole length of 3.3 mm, and a plate hole width of 2.3 mm. It accepts 1.5-mm and 2.0-mm diameter cortical bone screws. The larger plate (2.0/2.7) was 1.5 mm thick with a plate hole length of 3.8 mm and a plate hole width of 2.8 mm. It accepts 2.0-mm and 2.7-mm diameter cortical bone screws. The plates can be cut to the desired length and since the 2 types of plates have the same hole-to-hole distance of 6.0 mm, any 2 plates can be stacked on top of one another and still allowing screw insertion in any hole. Advantages of the VCP include: a large number of screw holes per unit length, allowing for placement of multiple screws in a fragment; the narrowness and the thinness of the plate; and the ability to customize the thickness of the plate by stacking VCPs of the same or different thicknesses.

## 3.8 IMPLANT SELECTION

Young dogs weighing less than 6 kgs were stabilised with 2.0 mm Veterinary Cuttable Plate, young dogs weighing 6-10 kgs were stabilised with 2.7 mm Veterinary Cuttable Plate whereas young dogs weighing more than 10 kgs were stabilised with stacking of two 2.0 mm Veterinary Cuttable Plates. The length of the plate required was decided by measuring the length of normal contralateral bone in mediolateral view.

## 3.9 PREOPERATIVE PREPARATION

### 3.9.1 Patient preparation

The fractures were temporarily stabilised with modified Robert-Jones bandage with or without the use of splints till the day of surgery. The owners were advised to withhold food for 12 hours and water for about 6 hours prior to surgery. The affected limb was aseptically prepared by clipping the hair from a wide area surrounding the surgical site including the proximal and distal joints. The operative site was shaved and scrubbed using povidone-iodine surgical scrub, followed by application of surgical spirit and 5% povidone iodine. Ringer's lactate was administered intravenously throughout the duration of surgery (Das *et. al.* 2012).

### 3.9.2 Premedication

All dogs were premedicated with inj. atropine sulphate[1] @ 0.04 mg/kg b.wt. i.m. 15 minutes before surgery.

### 3.9.3 Anaesthesia

General anaesthesia was induced using inj. ketamine hydrochloride[2] @ 5 mg/kg b.wt. and inj. midazolam[3] @ 0.2 mg/kg b.wt. i.v. Following induction of anaesthesia, the

1. Atromed – Etmed biotech, Baddi - 173 205 (H.P), India
2. Ketamax[*]50 – Troikaa pharmaceuticals Ltd., Dehradun – 248 197, Uttarakhand, India
3. Mezolam – Neon laboratories Ltd., Andheri – 400 093, Mumbai, India

dogs were intubated with endotracheal tubes of suitable size. General anaesthesia was maintained with 2 to 3% isoflurane[4].

## 3.10 SURGICAL TECHNIQUE

### 3.10.1 Patient positioning

The animals were positioned in lateral recumbency with affected limb uppermost for radius and lowermost for tibia fracture (Fig. 4 and 5).

### 3.10.2 Fracture reduction

Fracture reduction was accomplished by applying gentle traction and counter traction using pointed bone holding forceps and care was taken to prevent damage to periosteum and thin cortical bones.

### 3.10.3 Surgical procedure

#### 3.10.3.1 Radius

##### 3.10.3.1.1 Surgical approach to radius

An 8-11cm long linear incision was made on cranio-lateral aspect avoiding cephalic vein (Fig. 6) starting just above the antebrachiocarpal joint extending proximally. The deep antebrachial fascia was incised in the same line. An incision was given between the extensor carpi radialis and the common digital extensor. The extensor carpi radialis was elevated to expose the fracture site In case of distal fractures, the fascia of the abductor policis longus was incised and the muscle was retracted to expose fracture

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4. Isotray 250 - Troikaa pharmaceuticals Ltd., Thol – 382 728, Gujarat, India

Fig. 4 Photograph showing positioning and preparation of the limb for radius fracture repair

Fig. 5 Photograph showing positioning and preparation of the limb for tibia fracture repair

fragments (Fig. 7). Care was taken not to severe the cephalic vein as it crosses the distal portion of the radius.

### 3.10.3.1.2 Application of implant

Fracture reduction was accomplished by applying gentle traction and counter traction using pointed bone holding forceps and care was taken to prevent damage to periosteum and thin cortical bones. After reduction of fracture fragments, stabilisation was done using appropriate sized VCP. The plate was cut to the desired length according to the anticipated position of the screws with desired number of plate holes from the 300 mm VCP using standard pin cutter (Fig. 8). The VCP was positioned on the cranial surface of the radial diaphysis. Stacking of two VCPs was done to increase the rigidity of the implant, if needed (Fig. 9). The plate was applied as Elastic Plate Osteosynthesis according to the principles of bridge plating in young animals (i.e., use of a longer plate and fewer screws). Screw holes were drilled with appropriate size of drill bit (1.5 mm for 2.0 mm plate and 2.0 mm for 2.7 mm plate) using drill guide. While drilling hole, the site was flushed with normal saline to prevent thermal necrosis of the bone (Fig. 10). 2.0 mm or 2.7 mm cortical screws were inserted without tapping (Fig. 11). The cortical screws were placed on the two or three most proximal and two or three most distal holes of the plate leaving central plate span without screws as long as possible and included not less than three consecutive empty screw holes at the fracture site (Sarrau *et. al.* 2007) (Fig. 12). A third screw was implanted in both the fracture fragments when there was doubt regarding the handling of one or both initial screws. The proximal screws were inserted below the proximal growth plate and the distal screws were inserted above distal growth plate Two adjacent screws were inserted in different planes to increase the resistance to screw pullout and to increase the compliance of the bone-implant construct. The muscles were sutured with 2-0 polyglactin 910[5] in continuous pattern (Fig. 13). Subcuticular sutures were placed with 2-0 polyglactin 910 (Fig. 14). The skin incision was closed by cruciate mattress suture using nylon no. 0 (Fig. 15).

**3.10.3.2 Tibia**

**3.10.3.2.1 Surgical approach to Tibia**

A medial skin incision of about 7-12cm was made parallel to tibial crest along the entire length of the tibia upto medial malleolus to approach the fracture site (Fig. 16). The subcutaneous fascia was incised in the same line, care was taken to protect the dorsal branch of the saphenous vessels and nerve crossing the field at the mid shaft. The bone was exposed by incising the deep crural fascia on the medial shaft of the bone. The cranial tibial, popliteus and long digital flexor muscles were reflected from the bone. The fracture site was thus exposed (Fig. 17).

**3.10.3.2.2 Application of implant**

After reduction of fracture fragments, stabilisation was done using appropriate size of the VCP. The plate was cut to the desired length (Fig. 18) according to the anticipated position of the screws with desired number of holes from the 300 mm VCP using standard pin cutter. The VCP was positioned on the medial surface of the tibial diaphysis (Fig. 19). Stacking of two VCPs was done to increase the rigidity of the

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5. MITSU™ – Meril Endo Surgery Private Limited, Vapi, Gujarat- 396 191, India

Fig. 6 Photograph showing cranio-lateral skin incision for radius

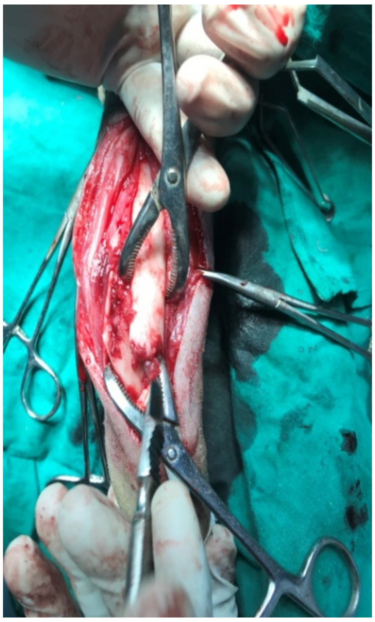


Fig. 7 Photograph showing exposure of fracture fragments - radius

Fig. 8 Photograph showing cutting of VCP to desired length with standard pin cutter

Fig. 9 Photograph showing stacking of VCP for radius fracture

Fig. 10 Photograph showing flushing of bone drilling site with normal saline

Fig. 11 Photograph showing insertion of screws without tapping

Fig. 12 Photograph showing stacked VCP in-situ with central screw holes unoccupied

Fig. 13 Photograph showing closure of muscles

Fig. 14 Photograph showing closure of subcutis

Fig. 15 Photograph showing closure of skin incision

Fig. 16 Photograph showing medial skin incision for tibia

Fig. 17 Photograph showing exposure of fracture fragments - tibia

Fig. 18 Photograph showing measurement of VCP length required for fracture stabilisation

Fig. 19 Photograph showing positioning of VCP on medial surface - tibia

Fig. 20 Photograph showing stacking of VCP - tibia

Fig. 21 Photograph showing VCP in-situ- tibia

Fig. 22 Photograph showing closure of muscles

Fig. 23 Photograph showing closure of subcutis

implant, if needed (Fig. 20). The procedure for application of plate (Fig. 21) and closure of surgical incision (Fig. 22 and 23) were similar to radius.

## 3.11 POSTOPERATIVE CARE AND MANAGEMENT

The dogs were kept under observation till complete recovery. Surgical wound was dressed with 5% povidone-iodine using sterile gauze. Modified Robert Jones bandage was applied to prevent post-operative edema and to provide additional support till four weeks post-surgery. The dressing and bandage were changed on 3rd and 10th post-operative day and thereafter at weekly intervals. The skin sutures were removed on 10th post-operative day. Post-operatively, all the dogs were given inj. taxim[6] @ 22mg/kg b.wt. s.i.d i.m. for 7 days and syr. melonex[7] @ 0.2mg/kg b.wt. s.i.d orally for 3 days. Owners were advised to restrict the activity of the animals for 2 weeks after surgery and limited exercise with leash walk for 4-6 weeks till complete bone healing.

## 3.12 EVALUATION OF FRACTURE HEALING

The outcome of fracture stabilisation of radius and tibia fracture by Elastic Plate Osteosynthesis with VCP was evaluated based on clinical, radiological, lameness grading, limb usage and biochemical parameters.

### 3.12.1 Clinical evaluation

Clinical evaluation was carried out at immediate post-operative, 15th, 30th and 60th post-operative days for the presence of swelling, exudation, suture dehiscence and weight

6. Taxim – Alkem Health Science, South Sikkim – 737137 India

7. Melonex – Intas pharmaceuticals Ltd., Matoda – 382 210, India

bearing in all the dogs. The post-operative day on which the dog started bearing weight was recorded. The appearance of the suture line was also closely examined every alternate day until the sutures were removed.

### 3.12.2 Lameness grading

A lameness grade was assigned to all the cases after assessment during preoperative, immediate post-operative, 15$^{th}$, 30$^{th}$ and 60$^{th}$ postoperative days based on the weight bearing pattern during stance and while at walking (Dymond *et. al.* 2010).

Grade 0 - No lameness

Grade 1 - Mild lameness – occasional gait abnormality.

Grade 2 – Moderate lameness – obvious gait abnormalities,

Grade 3 - Moderate lameness – obvious gait abnormality and occasional non-weight bearing

Grade 4 – Severe lameness – Consistently non – weight bearing.

### 3.12.3 Radiographic evaluation

Two orthogonal views of operated limb at 90 degrees were taken at preoperative, immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ postoperative days in all the cases for assessing apposition and alignment of fracture fragments, implant position, cortical continuity, radiographic healing, screw loosening, type of fracture healing and bone remodelling using Seimen's helio plus D 500 mA X-ray unit.

### 3.12.4 Limb usage

Based on the periodical clinical examinations, the functional limb outcome/ limb usage during postoperative period was assessed in all the animals and the animals were categorized as excellent, good, fair and poor (Clark, 1986).

Excellent : No lameness, no more than 15° loss of range of motion compared to the dog's opposite limb, no post-operative complications

Good : Moderate occasional lameness, not required treatment, 20° to 30° loss of range of motion, no postoperative complications

Fair : Moderate persistent lameness requiring treatment, 40° to 60° loss of range of motion

Poor : Persistent severe lameness with loss of greater than 40° range of motion.

## 3.13 COMPLICATIONS

### 3.13.1 Intraoperative complications

Intra operative complications, if any, were recorded in all the cases.

### 3.13.2 Postoperative complications

Postoperative complications, if any, were recorded in all cases during the course of treatment and study.

## 3.14 IMPLANT REMOVAL

The plate was removed 5-8 weeks post-surgery in all the cases after observing radiographic bone healing. Plate removal was done under general anaesthesia, after aseptic preparation of site. Craniolateral incision was given for radius and medial incision for tibia fracture. Subcutaneous tissue and muscles were separated. After exposure of plate, screws were removed from proximal and distal fragments and the plate was removed. Surgical wound was closed in routine manner. The dogs were administered antibiotic for 5 days and analgesics for 3 days.

## 3.15 SERUM BIOCHEMICAL EVALUATION

Blood sample was collected and serum was separated in all the cases on preoperative, immediate, $15^{th}$, $30^{th}$ and $60^{th}$ postoperative days for estimation of serum calcium, phosphorous and alkaline phosphatase.

### 3.15.1 Serum calcium

The serum calcium levels (mg/dL) were determined by Arsenazo- III method with kit supplied by Asritha Diatech India Pvt. Ltd., Hyderabad, India.

### 3.15.2 Serum phosphorus

The serum inorganic phosphorus (mg/dL) levels were estimated by Molybdate U.V. method using kit marketed by Coral Clinical Systems, a division of tulip diagnostics (P) Ltd., Uttarakhand, India.

### 3.15.3 Serum alkaline phosphatase

Serum alkaline phosphatase (IU) was estimated by Tris Carbonate buffer, Kinetic Kit method using Erba alkaline phosphatase kit manufactured by Transasia Bio-meicals Ltd., Baddi, Solan District, Himachal Pradesh, India.

## 3.16 STATISTICAL ANALYSIS

The data collected were statistically analyzed using S P S S-ANOVA Post Hoc test in Tukey H S D.

# CHAPTER - IV

# RESULTS

## 4.1 INCIDENCE

The total number of fracture cases recorded in dogs during the period of study i. e. May, 2016 to April, 2018 were 272 of which long bone fractures were 246 (90.40% of total fractures). Among the long bone fractures incidence was highest in femur (40.24%) followed by radius and ulna (26.83%), tibia and fibula 63 (25.61%) and least in humerus 18 (7.32%) (Fig. 24).

### 4.1.1 Age, Sex and Breed wise incidence of fractures in young dogs

Out of 129 fractures in radius and tibia incidence was more in adults aged >1 year (61.24%) than young dogs aged < 1 year (38.76%) (Fig. 25). Among 50 young dogs with radius and tibia fractures, incidence was more in males (58.0%) than in females (42.0%) (Fig. 26). Among different breeds presented, incidence was more in Mongrels (46.0%) followed by Pomeranian (18.0%), German Shepherd Dog (14.0%), Spitz (12.0%), Labrador Retriever (8.0%) and Dalmatian (2.0%) (Table. 2 and 3) (Fig. 27).

Out of 50 radius and tibia fractures in young dogs 11 (22.0%) were proximal, 21 (42.0%) were diaphyseal and 18 (36.0%) were distal fractures (Fig. 28). Among these 50 radius and tibia fractures in young dogs 34 (68.0%) were transverse fractures, 11 (22.0%) were oblique fractures, 4 (8.0%) were comminuted and 1(2.0%) was spiral fracture (Fig. 29).

**Table. 2 Age wise incidence of radius and tibia fractures in dogs**

| S.No | Age | Radius | Tibia | Total |
|---|---|---|---|---|
| 1. | < 1 year | 27 (54.0%) | 23 (46.0%) | **50** (38.76%) |
| 2. | > 1 year | 39 (49.37%) | 40 (50.63%) | **79** (61.24%) |
| **Total** | | **66** (51.16%) | **63** (48.84%) | **129** (100%) |

**Table. 3 Breed and Sex wise incidence of radius and tibia fractures in young dogs**

| S.No | Breed | Radius and ulna | | Tibia and fibula | | Total | | Grand Total |
|---|---|---|---|---|---|---|---|---|
| | | M | F | M | F | M | F | |
| 1. | Mongrel | 8 | 5 | 6 | 4 | 14 | 9 | 23 (46.0%) |
| 2. | Pomeranian | 4 | 2 | 1 | 2 | 5 | 4 | 9 (18.0%) |
| 3. | German Shepherd Dog | 2 | 1 | 2 | 2 | 4 | 3 | 7 (14.0%) |
| 4. | Spitz | 1 | 3 | 1 | 1 | 2 | 4 | 6 (12.0%) |
| 5. | Labrador Retriever | 0 | 0 | 3 | 1 | 3 | 1 | 4 (8.0%) |
| 6. | Dalmatian | 1 | 0 | 0 | 0 | 1 | 0 | 1 (2.0%) |
| **7.** | **Total** | **16** | **11** | **13** | **10** | **29** | **21** | **50** (100%) |

**Fig. 24 Graph showing incidence of long bone fractures in dogs**

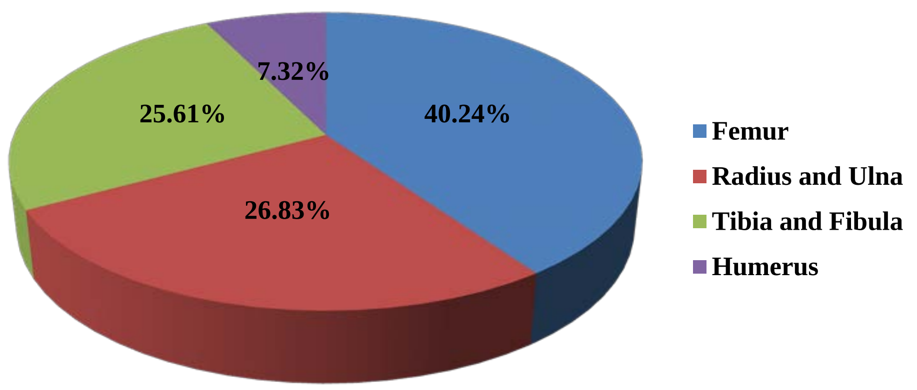



**Fig. 25 Graph showing age wise incidence of radius and tibia fractures**

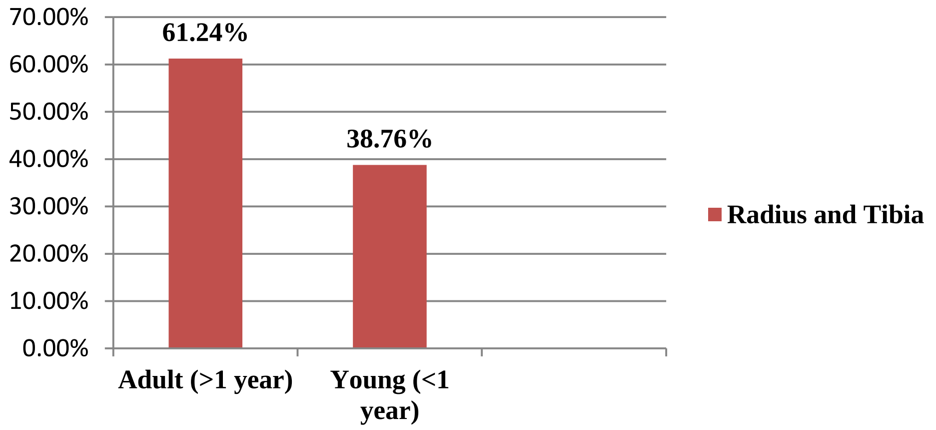


Fig. 26 Graph showing sex wise incidence of radius and tibia fractures in young dogs

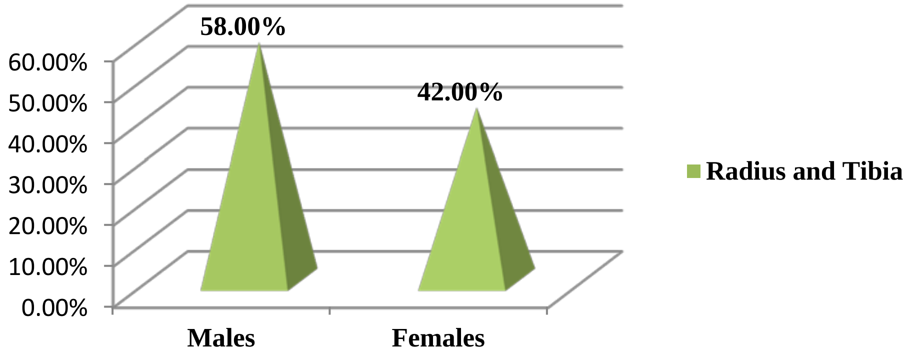
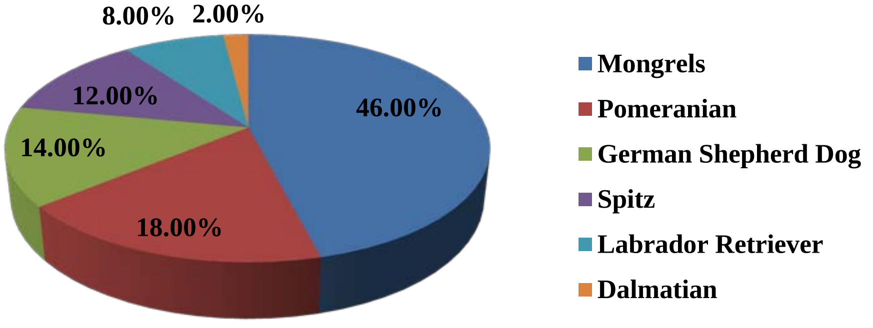



Fig. 27 Graph showing breed wise incidence of radius and tibia fractures in young dogs



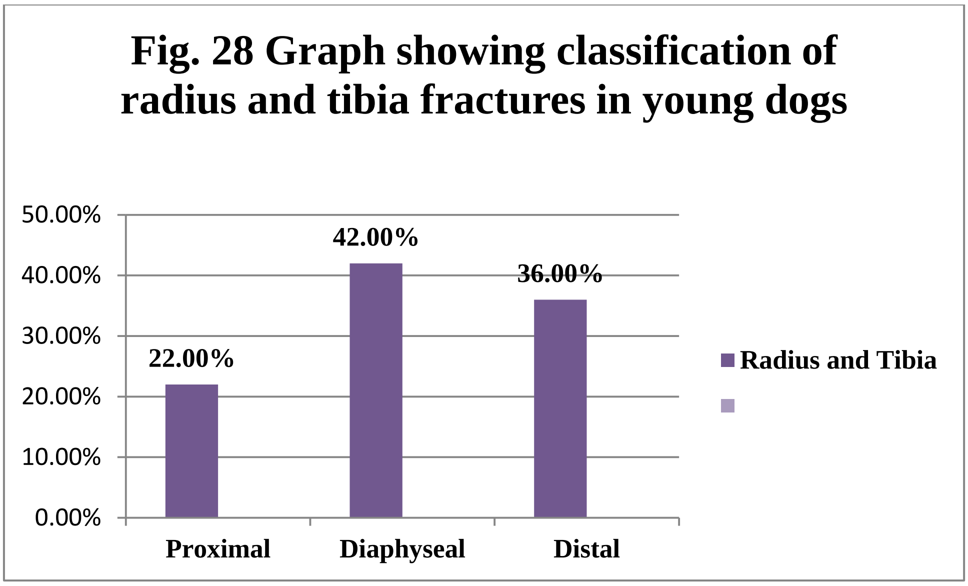


Fig. 28 Graph showing classification of radius and tibia fractures in young dogs
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
22.00%
42.00%
36.00%
Proximal
Diaphyseal
Distal
Radius and Tibia

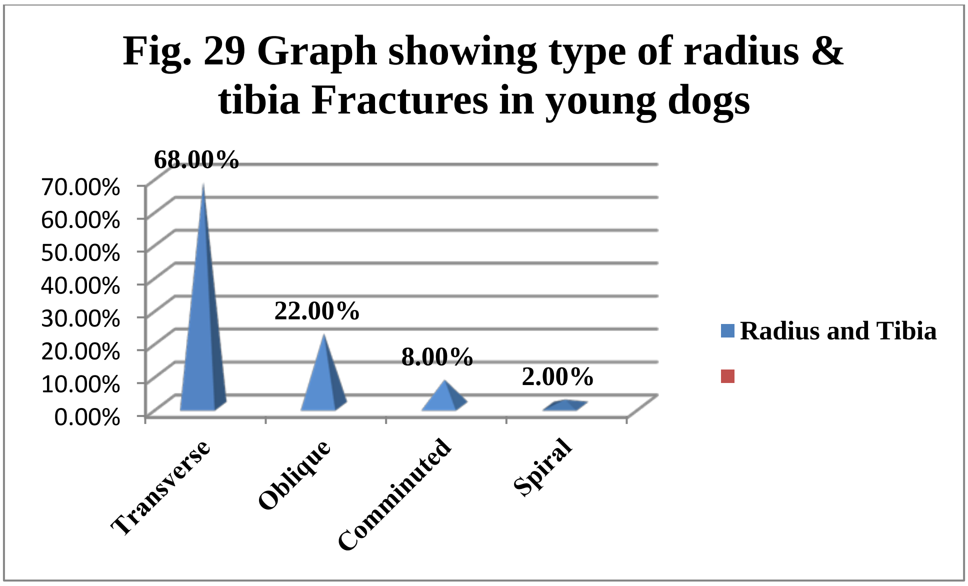


Fig. 29 Graph showing type of radius & tibia Fractures in young dogs
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
68.00%
22.00%
8.00%
2.00%
Transverse
Oblique
Comminuted
Spiral
Radius and Tibia

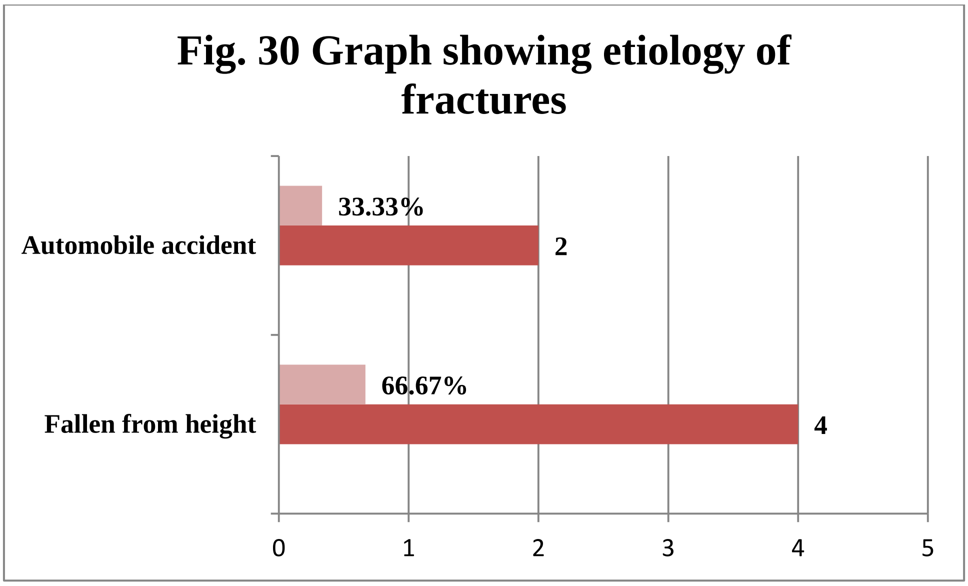


Fig. 30 Graph showing etiology of fractures
Automobile accident
33.33%
2
Fallen from height
66.67%
4
0
1
2
3
4
5

## 4.2 ETIOLOGY

The causes of radius and ulna and tibia and fibula fractures were determined based on the history for the 6 cases included in the study. In the present study the main cause was fall from a height (66.67%) (case no 3,4,5 and 6) followed by automobile accident (33.33 % ) (case no.1 and 2) (Table. 4) (Fig. 30).

**Table. 4 Etiology of fractures**

| S. No | Cause of fracture | Case number | Total | Per Cent (%) |
|---|---|---|---|---|
| 1. | Fall from height | 3,4,5 and 6 | 4 | 66.67 |
| 2. | Automobile accident | 1 and 2 | 2 | 33.33 |
| | **Total** | | **6** | **100** |

## 4.3 CLINICAL EXAMINATION AND DIAGNOSIS

All six dogs presented for treatment either with radius or tibia fracture exhibited clinical signs like non-weight bearing of the affected limb, swelling, pain, crepitus and abnormal mobility with or without soft tissue damage. Lateral and craniocaudal radiographic views taken at 90 degrees angle of the fractured bones were satisfactory in providing confirmatory diagnosis.

## 4.4 CLASSIFICATION OF FRACTURES

Lateral and craniocaudal radiographic views taken at 90 degrees angle of the fractured bones were satisfactory in providing confirmatory diagnosis, enabled fracture classification and pre-operative decision making. Fractures were classified as follows based on AO classification.

Out of 6 cases included in the study, two cases (case no. 2 and 4) were comminuted, slight overriding distal $3^{rd}$ fracture of right radius and ulna designated as **2 2 B 2** (Fig. 31 and 32), two cases (case no. 5 and 6) were complete, midshaft, oblique/spiral, over riding tibio fibular fracture designated as **4 2 A 2** (Fig. 33), one case (case no. 3) was complete, oblique, overriding proximal $3^{rd}$ fracture of left tibia and fibula designated as **4 2 A 2** (Fig. 34) and one case (case no. 1) was complete, transverse, overriding proximal $3^{rd}$ fracture of left tibia and fibula designated as **4 2 A 3** (Fig. 35) (Table. 5).

## 4.5 PREOPERATIVE PLAN FOR IMPLANT SELECTION

Pre-operative plan using the medio-lateral and craniocaudal radiographic views of the affected limb and contralateral normal limb helped in determining the length of the Veterinary Cuttable Plate i.e., number of plate holes required for fracture reduction and proved satisfactory. Age, weight of the dog and size of the bone considered in choosing the size of the VCP and cortical screws required were satisfactory.

**Table. 5 AO classification of fractures presented for treatment in dogs**

| CASE No. | BREED | AGE (Months) | SEX | WEIGHT (Kg) | LIMB INVOLVED | ETIOLOGY | FRACTURE TYPE AND CLASSIFICATION |
|---|---|---|---|---|---|---|---|
| 1. | Spitz | 3 | F | 3.4 | L | Automobile accident | Complete, transverse, overriding proximal 3rd fracture of left tibia and fibula **- 42A3** |
| 2. | German Shepherd Dog | 8 | F | 16.5 | R | Automobile accident | Comminuted, slight overriding distal 3rd fracture of right radius and ulna with a fissure extending upto proximal third – **22B2** |
| 3. | Mongrel | 4 | F | 7.2 | R | Fall from height | Complete, oblique, proximal 3rd, slightly displaced right tibiofibular fracture **- 42A2** |
| 4. | Mongrel | 6 | F | 6.8 | R | Fall from height | Comminuted, slight overriding distal 3rd fracture of right radius and ulna – **22B2** |
| 5. | Pomeranian | 7 | F | 5.9 | L | Fall from height | Complete, midshaft, long oblique, overriding tibio fibular fracture **- 42A2** |
| 6. | Labrador Retriever | 6 | M | 19.6 | L | Fall from height | Complete, midshaft, spiral, unstable tibio fibular fracture **- 42A2** |

M-Male F-Female L-Left R-Right

Fig. 31 Skiagram showing mediolateral view of comminuted, slight overriding distal 3rd fracture of right radius and ulna in a 8 months old female German Shepherd Dog

Fig. 32 Skiagram showing cranio-caudal view of comminuted, slight overriding distal 3rd fracture of right radius and ulna in a 6 months old female Mongrel dog

Fig. 33 Skiagram showing mediolateral view of complete, midshaft, spiral, unstable tibio fibular fracture in a 6 months old male Labrador Retriever dog

Fig. 34 Skiagram showing cranio-caudal view of complete, oblique, proximal 3rd, slightly displaced right tibiofibular fracture in a 4 months old female Mongrel dog

Fig. 35 Skiagram showing mediolateral view of complete, transverse, overriding proximal 3rd fracture of left tibia and fibula in a 3 months old female Spitz dog

## 4.6 PREMEDICATION AND ANAESTHESIA

Atropine sulphate premedication with ketamine-midazolam anaesthetic induction was satisfactory for intubating the patient in all the cases. 2-3% isoflurane anaesthesia with 100% oxygen provided satisfactory surgical plane of anaesthesia throughout the surgical procedure without any complications in all the cases.

## 4.7 SURGICAL TECHNIQUE

### 4.7.1 Positioning and surgical approach to Radius

Positioning of animals in lateral recumbency with affected limb uppermost was satisfactory and provided easy access to the bone. The craniolateral approach facilitated easy and adequate exposure, reduction and alignment of fracture fragments and positioning of the implant for fracture stabilisation.

### 4.7.2 Positioning and surgical approach to Tibia

Positioning the animal in lateral recumbency with affected limb lowermost provided easy access to the medial aspect of the tibia. Medial approach for tibia facilitated easy and adequate exposure, reduction and alignment of fracture fragments and positioning of the implant for fracture stabilisation.

### 4.7.3 Application of VCP

The Veterinary Cuttable Plates and screws were selected based on the pre-operative plan were found to be appropriate in the present study. After exposure of the bone, the fracture fragments were reduced with the help of pointed bone holding forceps without damaging the periosteal layer and anatomical reduction was not attempted in all the cases. VCP was cut to appropriate length with the help of pin cutter. No difficulty was encountered in cutting the plate between the holes using pin cutter. VCP maintained adequate reduction and stability of the fracture with good contact between the fracture fragments in all the cases. No technical difficulties were encountered during application of VCP. Elastic Plate Osteosynthesis was carried out employing bridge plating principles in all the cases. Two or three screws were applied without tapping in most proximal and most distal plate holes of both fracture fragments away from fracture site without involving growth plates. A third screw was inserted when there was doubt concerning the stability of one or both of the previous screws inserted. In case no. 1, 11 holed 2.0 mm VCP with 3 screws each in most proximal and most distal plate holes was used. In case no. 2, 18 holed 2.0 mm stacked VCP with 2 screws each in most proximal and most distal plate holes was used. In case no. 3, 16 holed 2.7 mm VCP with 3 screws each in most proximal and most distal plate holes was employed. In case no. 4, 14 holed 2.7 mm VCP with 2 screws each in most proximal and most distal plate holes was used. In case no. 5, 13 holed 2.0 mm VCP with 2 screws each in most proximal and most distal plate holes was used, while in case no. 6, 20 holed 2.0 mm stacked VCP with 2 screws each in most proximal and most distal plate holes was used for stabilisation of the fracture. In case no. 2 and 6, stacked plating was performed with 2.0mm VCP to increase the rigidity of implant-bone construct owing to more weight of the animals. No complications were observed intraoperatively.

The mean time taken for surgery was 43 mins (34 and 50 mins).

The details of the implants used in each case were given in Table. 6.

**Table. 6 Specification of the implants used for VC Plating in dogs**

| Case No. | Breed | Age | Weight (Kg) | Type of fracture | Implant specifications |
|---|---|---|---|---|---|
| 1. | Spitz | 3 | 3.4 | Complete, transverse, overriding proximal 3rd fracture of left tibia and fibula | 11 holed 2.0 mm VCP with 3 screws each in most proximal and most distal plate holes |
| 2. | German Shepherd Dog | 8 | 16.5 | Comminuted, slight overriding distal 3rd fracture of right radius and ulna with a fissure extending upto proximal third | 18 holed 2.0 mm stacked VCP with 2 screws each in most proximal and most distal plate holes |
| 3. | Mongrel | 4 | 7.2 | Complete, oblique, proximal 3rd , slightly displaced right tibiofibular fracture | 16 holed 2.7 mm VCP with 3 screws each in most proximal and most distal plate holes |
| 4. | Mongrel | 6 | 6.8 | Comminuted, slight overriding distal 3rd fracture of right radius and ulna | 14 holed 2.7 mm VCP with 2 screws each in most proximal and most distal plate holes |
| 5. | Pomeranian | 7 | 5.9 | Complete, midshaft, long oblique, over riding tibio fibular fracture | 13 holed 2.0 mm VCP with 2 screws each in most proximal and most distal plate holes |
| 6. | Labrador Retriever | 6 | 19.6 | Complete, midshaft, spiral, unstable tibio fibular fracture | 20 holed 2.0 mm stacked VCP with 2 screws each in most proximal and most distal plate holes |

## 4.8 POST-OPERATIVE CARE AND MANAGEMENT

Post-operatively, all the dogs were given inj. cefotaxime @ 22 mg/kg b.wt. i.m. s.i.d for one week and inj. meloxicam @ 0.2 mg/kg b.wt. i.m. s.i.d for 3 days. Modified Robert Jones bandage applied to the repaired limb, provided good adjunct support to the internal fixation and helped in further stabilisation of the reduction and prevented the post-operative limb edema. Wound dressing was done on 3$^{rd}$ post-operative day and 10$^{th}$ post-operative day using 5% povidone-iodine. The owners were advised to restrict movement for 2 weeks post-surgery and leash walk upto 4-6 weeks post-surgery. Skin sutures were removed on 10$^{th}$ post-operative day.

## 4.9 EVALUATION OF FRACTURE HEALING

### 4.9.1 Clinical evaluation

Surgical wounds healed without any complications in all the cases.

### 4.9.2 Lameness grading

Lameness grading was given on the basis of gait and weight bearing during stance and walking in all cases at immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days (Table. 7).

Pre-operatively all the animals showed lameness grade of 4 with persistence of same grade during immediate post-operative day in all the animals except case no. 5 which had a lameness grade of 3 with weight bearing on paw.

Weight bearing was observed on 3$^{rd}$ post-operative day in case no. 2, 5 and 6 (Fig. 36). In case no. 3 weight bearing was observed on 5$^{th}$ post-operative day (Fig. 37), while in case no. 1 and 4 weight bearing was observed on 6$^{th}$ post-operative day (Fig. 38). All the cases showed placing of paw on floor with weight bearing and gait abnormality on 15th post-operative day with lameness grade 2 (Fig. 39).

On 30th post-operative day all the cases showed normal gait and weight bearing pattern without any lameness and had a lameness grade 0, except case no. 4 which had a lameness grade of 2 with gait abnormality.

On 60th post-operative day all the cases showed no lameness (grade 0) except case no. 4 which still had occasional mild gait abnormality (grade 1).

**Table. 7 Lameness grading following VC Plating in dogs**

| Case No. | Lameness grading | | | | |
|---|---|---|---|---|---|
| | Preoperative day | Post-operative days | | | |
| | | Immediate | Day 15 | Day 30 | Day 60 |
| 1. | 4 | 4 | 2 | 0 | 0 |
| 2. | 4 | 4 | 2 | 0 | 0 |
| 3. | 4 | 4 | 2 | 0 | 0 |
| 4. | 4 | 4 | 2 | 2 | 1 |
| 5. | 4 | 3 | 2 | 0 | 0 |
| 6. | 4 | 4 | 2 | 0 | 0 |

Fig. 36 Photograph showing weight-bearing on 3rd post-operative day in a 7 months old female Pomeranian dog

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Fig. 37 Photograph showing weight-bearing on 5th post-operative day in a 4 months old female Mongrel dog

Fig. 38 Photograph showing weight-bearing on 6$^{th}$ post-operative day in a 6 months old female Mongrel dog

Fig. 39 Photograph showing weight-bearing on 15$^{th}$ post-operative day –lameness grade 2 in a 6 months old male Labrador Retriever dog

**4.9.3 Radiographic evaluation**

Orthogonal radiographs of the repaired bone were taken at regular intervals viz, immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days to assess the position of implants, reduction, apposition and alignment of fracture fragments, progress of fracture healing and to determine the type of fracture healing (Table. 8).

Immediate post-operative radiographs revealed adequate apposition and alignment of fractured fragments with good cortical contact between the fractured fragments in all the cases (Fig. 40, 42 and 43). Stacking of 2.0mm VCP was done in case no. 2 and 6 (Fig. 41 and 44).

On 15$^{th}$ post-operative day, small bridging periosteal callus with cortical continuity suggestive of healing was observed in case no. 1, 3, 4 and 5 (Fig. 45, 46 and 47). However, the fracture line was visible in case no. 1. Large bridging periosteal callus with partial cortical continuity was observed in case no. 6. In case no. 6 the callus encroached the proximal plate on lateral aspect as evident from craniocaudal view (Fig. 48). In case no. 2 mild periosteal reaction bridging the fracture gap was noticed (Fig. 49). Implants were in-situ in all the cases with proper apposition and alignment of the fracture fragments in all the cases. In case no. 1 partial loosening of most proximal screw was observed, however, the screw was still holding the plate. A thin osteolytic area surrounding all the three proximal screws was noticed in case no. 3.

On 30$^{th}$ post-operative day, implants were in-situ with proper apposition and alignment of fracture fragments in all the cases. Complete cortical continuity with disappearance of fracture line suggestive of complete fracture healing i.e., radiographic

**Table. 8 Radiographic evaluation of fracture healing following VC Plating in dogs**

| Post-operative interval | Parameters studied | Case no. 1 | Case no. 2 | Case no. 3 | Case no. 4 | Case no. 5 | Case no. 6 |
|---|---|---|---|---|---|---|---|
| **Immediate** | I | + | + | + | + | + | + |
| | A | + | + | + | + | + | + |
| | AL | + | + | + | + | + | + |
| **15th day** | I | + | + | + | + | + | + |
| | A | + | + | + | + | + | + |
| | AL | + | + | + | + | + | + |
| | CC | ++ | + | ++ | ++ | + | ++ |
| | SL | + | - | - | - | - | - |
| **30th day** | I | + | + | + | + | + | + |
| | A | + | + | + | + | + | + |
| | AL | + | + | + | + | + | + |
| | CC | +++ | ++ | +++ | +++ | ++ | +++ |
| | RH | + | - | + | + | - | + |
| | PH | + | - | + | + | - | - |
| | SH | - | + | - | - | + | + |
| **60th day** | CC | +++ | +++ | +++ | +++ | +++ | +++ |
| | BR | ++ | - | ++ | ++ | - | ++ |
| | RH | +++ | + | +++ | +++ | + | +++ |
| | PH | + | - | + | + | - | - |
| | SH | - | + | - | - | + | + |

I – Implant position
A – Apposition of fracture fragments
AL – Alignment of fracture fragments

CC – Cortical continuity
RH – Radiographic Healing
SL – Screw loosening

PH - Primary healing
SH – Secondary healing
BR – Bone remodelling

Fig. 40 Skiagram showing mediolateral view of adequate apposition and alignment of fractured fragments on immediate POD in a 3 months old female Spitz dog

Fig. 41 Skiagram showing mediolateral view of adequate apposition and alignment of fractured fragments on immediate POD in a 8 months old female German Shepherd Dog

Fig. 42 Skiagram showing mediolateral view of adequate apposition and alignment of fractured fragments on immediate POD in a 4 months old female Mongrel dog

Fig. 43 Skiagram showing mediolateral view of adequate apposition and alignment of fractured fragments on immediate POD in a 6 months old female Mongrel dog

Fig. 44 Skiagram showing cranio-caudal view of adequate apposition and alignment of fractured fragments on immediate POD in a 6 months old male Labrador Retriever dog

Fig. 45 Skiagram showing cranio-caudal view of small bridging periosteal callus with cortical continuity on $15^{th}$ POD in a 3 months old female Spitz dog

Fig. 46 Skiagram showing mediolateral view of small bridging periosteal callus with cortical continuity on $15^{th}$ POD in a 4 months old female Mongrel dog

Fig. 47 Skiagram showing mediolateral view of small bridging periosteal callus with cortical continuity on $15^{th}$ POD in a 6 months old female Mongrel dog

Fig. 48 Skiagram showing mediolateral view of large bridging periosteal callus with partial cortical continuity on $15^{th}$ POD in a 6 months old male Labrador Retriever dog

Fig. 49 Skiagram showing mediolateral view of mild periosteal reaction bridging the fracture gap on 15th POD in a 8 months old female German Shepherd Dog

Fig. 50 Skiagram showing mediolateral view of complete radiographic union on 30th POD in a 4 months old female Mongrel dog

Fig. 51 Skiagram showing mediolateral view of complete cortical continuity with disappearance of fracture line on 30th POD in a 6 months old female Mongrel dog

Fig. 52 Skiagram showing mediolateral view of complete cortical continuity with disappearance of fracture line (secondary healing) on 30th POD in a 6 months old male Labrador Retriever dog

Fig. 53 Skiagram showing cranio-caudal view of remodelling of bone $60^{th}$ POD in a 3 months old female Spitz dog

Fig. 54 Skiagram showing mediolateral view of remodelling of bone $60^{th}$ POD in a 4 months old female Mongrel dog

Fig. 55 Skiagram showing mediolateral view of remodelling of bone $60^{th}$ POD in a 6 months old female Mongrel dog

Fig. 56 Skiagram showing mediolateral view of remodelling of bone $60^{th}$ POD in a 6 months old male Labrador Retriever dog

union was observed in case no. 1, 3, 4 and 6 (Fig. 50, 51 and 52). The fracture line was visible in case no. 2 and 5. Primary healing was observed in case no. 1, 3 and 4, whereas secondary healing with huge periosteal callus spanning the entire shaft was observed in case no. 6. In case no. 6 the callus encroaching the proximal portion of the plate on lateral aspect was observed in craniocaudal view. The partial screw loosening of most proximal observed in case no. 1 did not affect the stability of implant-bone construct and the fracture healing progressed normally. No further screw loosening was observed on $30^{th}$ post-operative day.

On $60^{th}$ post-operative day, implants were in-situ with proper apposition and alignment of fracture fragments in all the cases. Complete cortical continuity with disappearance of fracture line indicating radiographic union of the fracture was observed in case no. 2 and 5. Secondary healing was observed in both the cases, however, the size of the periosteal callus was small in case no. 2. Remodelling of the bone was observed in case no. 1, 3, 4 and 6 implants (Fig. 53, 54, 55 and 56).

Diaphyseal growth was undisturbed in all the cases and consistently occurred without loss of alignment or anatomical deformation of either epiphyses.

**4.9.4 Limb usage**

At $60^{th}$ post-operative day, all the animals were evaluated for functional limb outcome and grouped as excellent 3 (50.0%) (Case no. 2, 3 and 6), good 2 (33.33%) (Case no. 1 and 5) and fair 1 (16.67%) (Case no. 4) (Table. 9). In case no. 4 occasional gait abnormality was observed on $60^{th}$ post-operative day, though the fracture healed completely without any complications. The cause was unknown.

**Table. 9 Limb usage details following VC Plating in dogs**

| | Number of animals | Per Cent (%) |
|---|---|---|
| **Excellent** | 3 | 50.0 |
| **Good** | 2 | 33.33 |
| **Fair** | 1 | 16.67 |
| **Poor** | 0 | 0.0 |
| **Total** | 6 | 100.0 |

## 4.10 COMPLICATIONS

### 4.10.1 Intra-operative complications

No technical difficulties were encountered during application of VCP.

### 4.10.2 Post-operative complications

Partial loosening of most proximal screw was noticed in case no. 1 on 15$^{th}$ postoperative day. In case no.3 plate was exposed at proximal end on 8$^{th}$ post-operative week (Fig. 57).

## 4.11 IMPLANT REMOVAL

The plate was removed after 5-8 weeks post-surgery in all cases after observing radiographic union of the fracture. Plate removal was done under general anaesthesia and aseptic preparation of site. For tibia, medial incision was given over the plate and for radius craniolateral incision was given (Fig. 58). Subcutaneous tissue incised in the same

Fig. 57 Photograph showing exposure of plate at proximal end on 8th post-operative week in a 4 months old female Mongrel dog

Fig. 58 Photograph showing medial skin incision over the tibia for plate

Fig. 59 Photograph showing completely healed bone after removal of plate - 8th post-operative week in a 4 months old female Mongrel dog

Fig. 60 Skiagram showing mediolateral view of healed fracture after plate removal in a 4 months old female Mongrel dog

line and muscles were separated by blunt dissection. After exposure of plate, screws were removed from proximal and distal fragments using appropriate hexagonal screw driver and the plate was removed (Fig. 59 and 60). Surgical wound was closed in routine manner. Antibiotics were administered for 5 days.

### 4.12 SERUM BIOCHEMISTRY

The mean ± SE values of serum calcium, phosphorous and alkaline phosphatase were recorded in Table. 10.

**Table. 10 Mean ± SE values of serum biochemical parameters following VC Plating in dogs**

| Day | Calcium (mg/dL) | Phosphorous (mg/dL) | Alkaline phosphatase (IU) |
|---|---|---|---|
| **Immediate** | 11.43$^{12}$±0.85 | 4.99±0.32 | 74.74$^{1}$±1.53 |
| **15** | 13.63$^{2}$±0.51 | 5.21±0.31 | 101.00$^{3}$±0.99 |
| **30** | 10.83$^{12}$±0.51 | 4.88±0.24 | 90.44$^{2}$±1.40 |
| **60** | 10.59$^{1}$±0.39 | 4.85±0.18 | 71.06$^{1}$±0.92 |

Means with different superscripts (numerical) between days in a group differ significantly ($P<0.01$).

### 4.12.1 Serum calcium

The post-operative serum calcium mean values showed a significant rise upto 15 days post-surgery followed by gradual decline and reaching base value on 30$^{th}$ day post-surgery. Significant difference in serum calcium levels was observed ($P<0.01$) between 15$^{th}$ and 60$^{th}$ postoperative days whereas no significant difference was observed between immediate and 15$^{th}$, immediate and 30$^{th}$, immediate and 60$^{th}$, 15$^{th}$ and 30$^{th}$ and 30$^{th}$ and 60$^{th}$ post-operative days ($P< 0.01$).

### 4.12.2 Serum phosphorous

There was no significant variation in serum phosphorous levels between different post-operative intervals and the values were within the normal range.

### 4.12.3 Serum alkaline phosphatase

Elevation in the serum alkaline phosphatase levels was observed up to 15$^{th}$ post-operative day and reached a peak on 15$^{th}$ post-operative day with a gradual return to normal base value on 60$^{th}$ post-operative day with statistically significant difference between day immediate and 15$^{th}$, immediate and 30$^{th}$, 15$^{th}$ and 30$^{th}$, 15$^{th}$ and 60$^{th}$ and 30$^{th}$ and 60$^{th}$ post-operative days whereas no significant difference was observed between immediate and 60$^{th}$ post-operative days ($P< 0.01$).

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# CHAPTER- V

# DISCUSSION

The total number of fracture cases recorded in dogs during the period of study i. e., May 2016 to April 2018 were 272, of which long bone fractures were 246 (90.40%) of total fractures. Among the long bone fractures incidence was highest in femur (40.24%), followed by radius and ulna (26.83%), tibia and fibula 63 (25.61%) and least in humerus 18 (7.32%). Similar findings were recorded by Aithal *et. al.* (1999), Harasen (2003), Kushwaha *et. al.* (2011), Jani *et. al.* (2014), Ramesh Chandra (2016) and Singh *et. al.* (2017). On the contrary, Thilagar and Balasubramanian (1988), Dvorak *et. al.* (2000) and Hari Krishna (2013) recorded highest fracture incidence in radius and ulna. Tambe *et. al.* (2012) recorded highest incidence in tibia.

Out of the 129 fractures in radius and tibia, incidence was more in adults aged >1 year (61.24%) than young dogs aged < 1 year (38.76%). Contradictory to this, Singh *et. al.* (1983), Thilagar and Balasubramanian (1988), Balagopalan *et. al.* (1995), Aithal *et. al.* (1999), Uma Rani *et. al.* (2004), Fazili *et. al.* (2005) and Singh *et. al.* (2017) recorded higher incidence in dogs < 1 year. In the present study, among 50 young dogs with radius and tibia fractures, incidence was more in males (58.0%) than in females (42.0%) as reported by Uma Rani *et. al.* (2004) and Fazili *et. al.* (2005). However, significantly higher incidence in males was observed by Aithal *et.*

*al.* (1999), Jani *et. al.* (2014) and Singh *et. al.* (2017). The higher incidence of fractures in males might be due to their wandering behavior and aggressive nature which were uncastrated males. Singh *et. al.* (2017) attributed it to higher population of male or males were preferred more as companion pet than the female in the area of study.

Among different breeds presented, incidence was more in Mongrels (46.0%) followed by Pomeranian (18.0%), German Shepherd Dog (14.0%), Spitz (12.0%), Labrador Retriever (8.0%) and Dalmatian (2.0%) in young dogs which was in accordance with by Dvorak *et. al.* (2000), Uma Rani *et. al.* (2004) and Jani *et. al.* (2014). On the contrary, Balagopalan *et. al.* (1995) reported highest incidence in Alsatian breed, Kushwaha *et. al.* (2011) in Spitz and Ramesh Chandra (2016) in Pomeranian breed.

Out of 6 cases of radius and tibia fractures included in the present study, the main etiological factor was fall from height (66.67%) followed by automobile accident (33.33%). (Kushwaha *et. al.*, 2011, Hari Krishna, 2013). On the contrary, Aithal *et. al.* (1999), Uma Rani *et. al.* (2004), Jani *et. al.* (2014) and Ramesh Chandra (2016) reported that automobile accident was the main cause for fracture incidence.

Detailed clinical and orthopaedic examination of the dogs presented for treatment helped in knowing the health status of the animal and probable location and type of fracture.

All the dogs presented for treatment exhibited symptoms like non-weight bearing of the affected limb, local swelling, pain, crepitus and abnormal mobility/angulation with or without soft tissue damage as observed by Johnson *et. al.* (1998b), Roush *et. al.* (1998) and Piermattei *et. al.* (2006).

Confirmatory diagnosis was achieved by taking two radiographic views at 90 degrees angle including joints above and below the fracture. The standard views taken for radius and tibia in the present study include cranio-caudal and medio-lateral (Roush *et. al.*, 1998, Langley-Hobbs, 2003, Kealy and McAllister, 2004 and Ramesh Chandra, 2016). The high quality radiographs obtained by using computerized radiography system helped in identifying the subtle co-existing lesions like fissures which in turn helped in taking proper care while applying the plate (Krauss *et. al.*, 2003). Cranio-caudal and medio-lateral radiographs taken at 90 degrees angle were proved to be useful in confirming the diagnosis, identifying the location, to assess fracture configuration, classification of fractures and selection of appropriate implant (Roush *et. al.*, 1998).

The fractures were classified according to anatomical location and direction of fracture line in all the young dogs presented with radius and tibia fracture (Denny and Butterworth, 2000). Out of 50 radius and tibia fractures in young dogs 11 (22.0%) were proximal, 21 (42.0%) were diaphyseal and 18 (36.0%) were distal fractures as observed by Tambe *et. al.* (2012). Singh *et. al.* (1999) reported higher incidence of transverse fractures (40.0%) followed by overriding (30.0%), oblique (23.3%) and distracted (1.0%). In the present study, 68.0% were transverse fractures, 22.0% were oblique fractures, 8.0% were comminuted and 2.0% were spiral fractures in concurrence with Uma Rani *et. al.* (2004), Kushwaha *et. al.* (2011) and Rhangani (2014) whereas Balagopalan *et. al.* (1995) observed more occurrence of oblique fractures than transverse fractures. In the present study, all the fractures were closed and mostly unstable (Hari Krishna, 2013).

Fractures were classified based on AO classification (Unger *et. al.*, 1990). Out of the six fractures included in the study two cases (case no. 2 and 4) were comminuted, slight overriding distal 3rd fracture of right radius and ulna designated as **2 2 B 2**, two cases (case no. 5 and 6) were complete, midshaft, oblique/spiral, over riding tibio fibular fracture designated as **4 2 A 2**, one case (case no. 3) was complete, oblique, overriding proximal 3rd fracture of left tibia and fibula designated as **4 2 A 2** and one case (case no. 1) was complete, transverse, overriding proximal 3rd fracture of left tibia and fibula designated as **4 2 A 3.**

Preoperative medio-lateral and cranio- caudal radiographic views of the affected bone and contralateral normal bone proved satisfactory in determining the length of Veterinary Cuttable Plate i.e., number of plate holes required for fracture fixation (Dejardin and Cabassu, 2008 and Heo *et. al.*, 2012). Age, weight of the dog and size of the bone considered in choosing the size of the VCP and cortical screws required was satisfactory. Dogs weighing less than 6 kg were stabilised with 2.0 mm Veterinary Cuttable Plate, dogs weighing 6-10 kg were stabilised with 2.7 mm Veterinary Cuttable Plate whereas young dogs weighing more than 10 kg were stabilised with stacked 2.0 mm Veterinary Cuttable Plates. No major deviations were noticed in the plate and screw selected.

With holding of the food for 12 hours and with holding the water 6 hours prior to surgery were satisfactory in preventing the regurgitation of food during induction as observed by Gupta (2005) and Bhatia (2010). On the contrary, Dwivedi *et. al.* (2009) recommended with holding of food 24 hours prior to surgery. Aseptic preparation and proper draping of the patient during surgery and administration of antibiotics 30 minutes prior to induction prevented the postsurgical surgical infections (Lidwell, 1984 and Penwick, 1985).

Premedication with atropine sulphate @ 0.04 mg/kg b.wt. administered i.m. 15 minutes prior to induction reduced the salivary and bronchial secretions and prevented vagal stimulation of heart as observed by Thurmon *et. al.* (1996). Induction of anaesthesia with ketamine and midazolam @ 5 mg/kg b.wt. and 0.2 mg/kg b.wt. respectively i.v. provided smooth and excitement free induction and facilitated easy intubation in all the dogs in concurrence with the Hellyer *et. al.* (1991). Anaesthesia maintained by 2-3 % isoflurane with 100% oxygen provided satisfactory surgical plane of anaesthesia throughout the orthopaedic procedure. Earlier workers Ranpariya *et. al.* (2013) reported that ketamine-midazolam induction and maintenance with isoflurane anaesthesia provided stable maintenance for orthopaedic procedures throughout the surgery as observed in the present study. Nithin (2016) opined that ketamine-diazepam induction and maintenance with isoflurane provide satisfactory anaesthesia for orthopaedic procedures.

Positioning of the patient in lateral recumbency with the affected limb uppermost for radius fracture and lowermost for tibial fracture provided easy and comfortable access to the bone with satisfactory exposure of the fracture fragments and plate application (Peirone *et. al.*, 2012). On the contrary, McCartney *et. al.* (2010) suggested dorsal recumbency for radius fracture repair.

Vaughan (1963) recommended antero-lateral approach for stabilisation of radial fractures and exposure of the radius involved separation of the extensor tendons which had become enveloped in the mass of fibrous tissue that circumscribed the fracture. Cranio-lateral approach used in the present study was satisfactory and provided easy access and sufficient exposure of the fractured fragments for fracture reduction and application of the plate with the affected limb uppermost. On the contrary, Piermattei and Johnson (2004), Pozzi and Lewis (2009) and Minto *et. al.* (2015) employed cranio-medial approach for radial fracture stabilisation with the affected limb lowermost. Earlier workers Ramirez and Macias (2016) reported that standard lateral approach with cranial skin incision application of VCP was convenient as observed in the present study. Whereas, Pozzi *et. al.* (2013) advocated either dorsomedial or dorsolateral approach with the fractured limb non-dependent for ORIF of radius and ulna fractures.

Medial incision starting proximally over the medial tibial condyle extending upto medial malleolus for tibial fracture stabilisation provided easy access and good exposure of the bone for application of the VCP and proved satisfactory which was in accordance with Piermattei (1993).

Fractures could be stabilised by external coaptation or internal fixation. Various internal fixation methods used for fracture fixation were pins, wires and plates and screws for rigid anatomical fixation. Radius and ulna and tibia and fibula were observed to be the most commonly fractured bones (Thilagar and Balasubramanian, 1988, McLain and Brown, 1982 and Dvorak *et. al.*, 2000). Radius fractures could be stabilised by different techniques viz., external coaptation/cast, bone plating (Ramirez and Macias, 2016), circular external skeletal fixators (Piras *et. al.*, 2011), distal radial fractures could be stabilised by mini plates or VCP or external fixator with cancellous bone graft (Harasen, 2003 and McCartney *et. al.*, 2010). Distal radial fracture repair was associated with high incidence of complications due to decreased intraosseous blood supply to the distal radius (Larsen *et. al.*, 1999). Colles fractures were stabilised by k-wires (McCartney *et. al.*, 2010). However, application of bone plate and screws for radius fracture provides very stable method of fixation (Larsen *et. al.*, 1999 and Milovancev and Ralphs, 2004).

Tibial fractures could be stabilised by external coaptation/cast, intramedullary pin, intramedullary pin plus cerclage wire, bone plates, plate rod (Reems *et. al.*, 2003) or external skeletal fixator based on fracture configuration.

Various methods were advocated for fracture repair in young dogs viz., external splints or casts, intramedullary pins, pins with splints, crossed pins, external skeletal fixation, plates and screws, plates supplemented by splints and plate-rod technique (McLain and Brown, 1982, Peirone *et. al.,* 2002 and Reems *et. al.*, 2003).

Bone plating was one of the common and reliable method of internal fixation for the management of fractures. Internal fixation of long bone diaphyseal fractures in puppies has to take into account the anatomical peculiarities of growing bones.

Depending on the breed, dogs reach skeletal maturity between 5 months (toy breeds) and 18 months (giant breeds) through a very rapid, biphasic growth rate. Generally, most skeletal growth occurs between 3 to 6 months of age (Cabassu, 2001 and Dejardin and Cabassu, 2008). Bones in young growing dogs significantly differ from mature adult bones both in structural and material properties characterised by lower strength and stiffness, as well as lower yield stress and elastic modulus. In addition, the diaphyseal cortices are considerably thinner in young dogs compared to adults which make them highly susceptible to implant failure via screw pullout (Dejardin and Cabassu, 2008). The main goal of surgical technique was to prevent iatrogenic damage to the growth plates and preservation of periosteum. These anatomical peculiarities make the fracture management techniques employed in adult dogs unfit for immature growing dogs.

Small fragment plates were often too weak for these fractures, while 2.7mm DCP which must be used with 2.7mm screws was too thick. The number of holes per unit length was an important factor in small dos because the fragments were often short and the stability of the fixation depends upon the number of screws inserted in a fragment. Considering plates in which

2.0mm screws could be used, the mini plates were often too weak and 2.0mm DCP was frequently of inadequate length and strength. A plate suitable for these fractures should fulfill the following requirements: 1. It should be cuttable to the desired length. 2. Its stiffness should be adjustable. 3. It should have a large number of holes per unit of plate length. 4. It should be usable with different screw sizes and 5. It should be economical to use and to stock (Bruse *et. al.*, 1989).

Dejardin and Cabassu (2008) listed different surgical options such as intramedullary nailing, Elastic Stable Intramedullary Nailing (ESIN), external fixation, plate osteosynthesis, Elastic Plate Osteosynthesis and MIPO using elastic fixation for repair of femur fractures in young dogs. However, anatomical reduction and rigid internal fixation during the early growth phase results in catastrophic implant failure via screw pull out which lead to the development of a new biological, Elastic Plate Osteosynthesis technique for treatment of femoral diaphyseal factures in puppies (Dejardin and Cabassu, 2008).

Review of literature revealed only few reports (Bruse *et. al.*, 1989, Sarrau *et. al.*, 2007 and Heo *et. al.*, 2012) mentioning the use of VCP for stabilisation of tibial fractures in young dogs and Heo *et. al.* (2012) reported successful tibial fracture repair by MIPO with VCP. No studies could be found regarding the use of VCP for treating radius fracture in young dogs. However, many authors reported its successful use in femur fracture repair in young dogs (Bruse *et. al.*, 1989, Cabassu, 2001, Sarrau *et. al.*, 2007 and Dejardin and Cabassu, 2008).

Sturmer (1996) described Elastic Plate Osteosynthesis as a biological method which was safer and superior to the rigid technique and could be applied to short oblique and transverse fractures. EPO technique with VCP employed in present study was found to be satisfactory and provided good stabilisation of the long bone fractures in young dogs as observed by Bruse *et. al.* (1989), Cabassu (2001), Dejardin and Cabassu (2008) and Guiot and Dejardin (2011).

Fracture reduction was achieved by gentle manipulation and applying traction and counter traction using pointed bone holding forceps and care was taken to prevent damage to periosteum and thin cortical bones.

According to the anticipated position of the screws in relation to the growth plates, a strip of plate with the desired number of holes was cut between holes to the desirable length (range between 11 to 20 holes) from the 300 mm VCP. The plate was cut with pin cutter (Bruse *et. al.*, 1989). The plate was applied according to the principles of bridge plating which was called EPO technique (use of a longer plate and fewer screws). The plate was applied on the cranial aspect in radius and medial aspect in tibia. The cortical screws were inserted without involving growth plates in the most two or three proximal and most two or three distal holes of the plate leaving central plate span without screws as long as possible and included not less than three consecutive empty screw holes at the fracture site. This resulted in rapid bone healing without premature closure of growth plates and implant failure. Similar findings observed were by Sturmer (1996), Cabassu (2001), Sarrau *et. al.* (2007), Dejardin and Cabassu (2008) and Gautier (2009) and the rapid bone healing was due to the elasticity of the plate between screws providing micromotion of the bone fragments.

In the present study, both the radial fractures were distal (Case no. 2 and 4) and among four tibial fractures, two were proximal (Case no. 1 and 3) and two were midshaft (Case no. 5 and 6). The fractures were stabilised by inserting two or three screws per fragment as far as possible from the fractures site which resulted in increased elasticity of the implant (Gentry *et.*

*al.*, 1993 and Dejardin and Cabassu, 2008). A third screw was inserted when there was doubt concerning the one or both of the initial screws. The screws were inserted without tapping and preserving the periosteum (Sarrau *et. al.*, 2007 and Dejardin and Cabassu, 2008). Two adjacent screws were oriented in different planes to increase the resistant to pullout. The screw distribution away from the fracture site decreases the stress riser effect of a single empty screw hole, reducing the risk of implant failure. It increased the overall compliance of the repaired implant-bone construct and reduced bone/screw interface stresses, which limits the risk of implant failure via screw pullout (Dejardin and Cabassu, 2008). The partial screw loosening observed in one case (Case no. 1) did not affect the stability of the implant, which was found not properly fitting during intraoperatively itself. This might be due to third screw implanted in that case. No screw pullout was observed in any of the cases. Gautier (2009) observed that the pullout force acting on the screw decreased as the working length of the plate was increased and plate screw density maintained to a maximum value of 0.5 and the distance between the innermost screws should be increased from fracture site, leaving at least two to three plate holes unoccupied at the fracture site to decrease the plate loading which in turn avoids fatigue failure in bridge plating technique as observed in the present study. Similar findings were reported by Bruse *et. al.* (1989), Sarrau *et. al.* (2007) and Dejardin and Cabassu (2008).

Dogs weighing >10kg were stabilised with full length stacked 2.0mm VCP to increase the rigidity and fatigue life of the implant and it provided good mechanical stability which was in concurrence with Bruse *et. al.* (1989), Fruchter and Holmberg (1991) and Hammel *et. al.* (2006). Zahn *et. al.* (2008) observed that the sectional geometry of the VCP was responsible for higher bending stiffness of the implant. They further stated that the stiffness of two stacked VCP was approximately equal to the sum of the stiffness of both plates.

Bruse *et. al.* (1989) opined that sandwiching two plates was essential when the fracture was comminuted, otherwise the plate might break or bend. On similar lines stack plating was performed for one case (Case no. 2) of comminuted fracture where as for the second case (Case no. 4) with an insignificant small wedge 2.7mm VCP was applied without stacking.

Guiot and Dejardin (2011) concluded that the VCP was the most compliant construct useful in juvenile dogs and cats because of its thinness, high hole density and flexible fixation in promoting bone healing as observed in the present study.

In the present study, the mean time taken for surgery was 43 minutes (34 to 50 minutes) as observed by Daniella (2017). On the contrary, Johnson *et. al.* (1998b) reported a mean surgery time of 116 minutes and Pozzi *et. al.* (2013) 113.5±37.9 minutes for plating in dogs.

Modified Robert Jones bandage applied to the repaired limb provided good adjunct support to the internal fixation, helped in further stabilisation of the reduction and prevented postoperative edema. This was in accordance with the findings of Tobias (1995), Denny and Butterworth (2000) and Mohindroo *et. al.* (2006). On the contrary, Sarrau *et. al.* (2007) advocated the use of only a small bandage on surgical wound. Schmokel *et. al.* (2007) recommended Modified Robert Jones bandage for several days and limiting exercise to indoor with leash walk for 4-6 weeks as followed in the present study.

In the present study, all the dogs were evaluated on the basis of gait and weight bearing pattern at immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days and lameness grading was given as per the method described by Dymond *et. al.* (2010). Pre-operatively, all the animals showed lameness grade of 4 with persistence of same grade on immediate post-operative day except case no. 5 which had a lameness grade of 3 with weight bearing on paw. Weight bearing was observed on 3rd post-operative day in case no. 2 and 6. In case no. 3, weight bearing was observed on 5th post-operative day while in case no. 1 and 4 weight bearing was observed on 6th post-operative day. McLaughlin *et. al.* (1992) observed minimal weight bearing on the operated limbs within four days of surgery and using the limb well within three weeks. All the cases showed placing of paw on floor with weight bearing and gait abnormality on 15th post-operative day with lameness grade 2. On 30th post-operative day all the cases showed normal gait and weight bearing pattern without any lameness and had a lameness grade 0, except case no. 4 which had a lameness grade of 2 with gait abnormality as observed by Gomaa *et. al.* (2016) and Rao *et. al.* (2017). On 60th post-operative day all the cases showed no lameness (grade 0) except case no. 4 which still had occasional mild gait abnormality with grade 1.

Lateral and cranio-caudal radiographic views were taken on immediate, 15th, 30th and 60th post-operative days for evaluation of implant position, fracture reduction, healing pattern and to assess the progress of fracture healing in all the cases were found to be satisfactory, which was in concurrence with Kraus *et. al.* (2003), Langley-Hobbs (2003), Kealy and McAllister (2004), Sarrau *et. al.* (2007) and Ramesh Chandra (2016).

Immediate post-operative radiographs revealed implants in-situ with adequate apposition and alignment of fractured fragments with good cortical contact between the fractured fragments in all the cases. The implants were stable in all the cases.

On 15th post-operative day, small bridging periosteal callus with cortical continuity suggestive of healing was observed in case no. 1, 3, 4 and 5. However, the fracture line was visible in case no. 1. Large bridging periosteal callus with partial cortical continuity was observed in case no. 6. In case no. 6 the callus encroaching the proximal portion of the plate on lateral aspect was observed in craniocaudal view. In case no. 2 mild periosteal reaction bridging the fracture gap was noticed. Implants were in-situ in all the cases with proper alignment and apposition of the fracture fragments. In case no. 1, partial screw loosening of most proximal screw was observed, however, still holding the plate. A thin osteolytic area surrounding all the three proximal screws was noticed in case no. 3. Cabassu (2001) and Dejardin and Cabassu (2008) observed partial callus formation and clinical union two weeks post-surgery.

On 30$^{th}$ post-operative day, implants were in-situ with proper alignment and apposition of fracture fragments. Complete cortical continuity with disappearance of fracture line suggestive of complete fracture healing i.e., radiographic union was observed in case no. 1, 3, 4 and 6. The fracture line was visible in case no. 2 and 5. Primary healing was observed in case no. 1, 3 and 4, whereas secondary healing with big periosteal callus covering the entire shaft was observed in case no. 6. In case no. 6 the callus encroaching the proximal portion of the plate on lateral aspect was observed in craniocaudal view. On contrary, secondary healing was observed by Bruse *et. al.* (1989), Cabassu (2001), Sarrau *et. al.* (2007) and Dejardin and Cabassu (2008). The partial screw loosening of most proximal screw observed in case no. 1 did not affect the stability of implant-bone construct and the fracture healing progressed normally. Sturmer (1996) observed healing by 3-6 weeks post-surgery with periost-soft tissue combination. Cabassu (2001) and Dejardin and Cabassu (2008) observed complete union by four weeks post-operatively. Sarrau *et. al.* (2007) noticed bone healing between 4-8 weeks post-surgery.

On 60$^{th}$ post-operative day, implants were in-situ with proper apposition and alignment of fracture fragments in all the cases. Complete cortical continuity with disappearance of fracture line indicating radiographic union of the fracture was observed in case no. 2 and 5. Secondary healing was observed in both the cases, however, the size of the periosteal callus was small in case no. 2. Remodelling of the bone was observed in case no. 1, 3, 4 and 6. Cabassu (2001) and Dejardin and Cabassu (2008) observed remodelling of the callus after two months and appeared to be advanced by four months.

Johnson *et. al.* (1998a) observed that biological fixation of comminuted fractures was associated with increased callus production, accelerated radiographic union, earlier gain in biomechanical strength and therefore, earlier return to function when compared to stable fracture fixation as observed in the present study. However, primary healing was observed in three cases contrary to his findings.

Diaphyseal growth was undisturbed in all cases and consistently occurred without loss of alignment or anatomical deformation of either epiphyses. Similar findings also observed by Dejardin and Cabassu (2008).

In the present study, at 60$^{th}$ post-operative day, all the animals were evaluated for limb usage and grouped as excellent, good, fair and poor (Clark, 1986). Out of 6 fractures treated 3 (50.00%) were excellent, 2 (33.33%) were good and 1 (16.67%) was fair. By 30$^{th}$ postoperative day, all the animals regained normal full functional limb whereas case no. 4 which had occasional mild gait abnormality even at 60$^{th}$ post-operative day. Limb usage was excellent to fair. Excellent outcome was noticed by Cabassu (2001) and Sarrau *et. al.* (2007) and Theoret and Moens (2007) observed good functional outcome. In case no. 4 lifting of the limb during stance was observed on 60$^{th}$ post-operative day, though the fracture healed completely without any complications. The cause was unknown.

In present study, no technical difficulties were encountered during application of VCP. No soft tissue irritation or difficulty in closing the skin incision was observed as reported by Tan and Balogh (2009). In all the animals the implants were stable, except case no.1 where partial loosening of most proximal screw was noticed on 15$^{th}$ postoperative day. Similar finding was noticed by Theoret and Moens (2007). However, Theoret and Moens (2007) observed complete screw loosening which was treated by screw removal. Gautier (2009) stated that the pullout force acting on the screw could be decreased by increasing the working length of the plate with the plate screw density maintained to a maximum value of 0.5. No plate bending was noticed in any of the cases. On the contrary, one implant failure i.e., plate bending was observed by Sarrau *et. al.* (2007) and Das *et. al.* (2012). In case no. 3 plate was exposed to outside at the proximal end on 8$^{th}$ week post-surgery. Implant associated osteomyelitis was not observed in the present study as reported by Rahal *et. al.* (2003).

The implants were removed 5-8 weeks post-surgery after evaluation of radiographic union of the fractures in all the cases under general anaesthesia following strict aseptic conditions (Johnson, 2013) as the immature dogs have growing bones. Piras (2000) advocated implant removal after 3 to 5 weeks to avoid plate entrapment by appositional bone growth and to avoid stress protection during the intense physical activity whereas Sarrau *et. al.* (2007) advised plate removal on an average of 4-8 weeks as soon as radiographic evidence of bone healing was noticed as performed in the present study.

In the present study, blood was collected and serum was separated on immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days for estimation of serum calcium, phosphorus and alkaline phosphatase in all the cases.

The post-operative serum calcium mean values showed a significant rise upto 15 days post-surgery and reached a peak on 15$^{th}$ post-operative day followed by gradual decline and reaching base value on $30^{th}$ day post-surgery. Significant difference in serum calcium levels was observed (P<0.01) between $15^{th}$ and $60^{th}$ postoperative days whereas no significant difference was observed between immediate and $15^{th}$, immediate and $30^{th}$, immediate and $60^{th}$, $15^{th}$ and $30^{th}$ and $30^{th}$ and $60^{th}$ post-operative days (P< 0.01). The increase in serum calcium level could be attributed to mineralization process at the osteotomy site (Nagaraja *et. al.*, 2003). Similar findings were observed by Bush (1991), Nagaraja *et. al.* (2003) and Kumar *et. al.* (2018). On the contrary Uma Rani *et. al.* (2012) observed reduction in serum calcium level on $3^{rd}$ post-operative day followed elevation up to $60^{th}$ post-operative day. Daniella (2017) found no significant difference in the serum calcium levels upto 60 days post-surgery. Julie (2005) observed significant decrease in serum calcium level by $4^{th}$ week.

No statistically significant difference was observed between the time periods with regard to serum phosphorus which was in accordance with Daniella (2017) and Kumar *et. al.* (2018). Contradictory to the present study, Siemens (1970) reported increased phosphorous levels on $30^{th}$ postoperative day and Nagaraja *et. al.* (2003) noticed significant increase in phosphorous levels upto $15^{th}$ postoperative day and attributed the same to necrotic disintegration of cells at the fracture site.

Elevation in the serum alkaline phosphatase levels was observed up to $15^{th}$ postoperative day and reached a peak on $15^{th}$ postoperative day with a gradual return to normal base value on $60^{th}$ postoperative day with statistically significant difference between day immediate and $15^{th}$, immediate and $30^{th}$, $15^{th}$ and $30^{th}$, $15^{th}$ and $60^{th}$ and $30^{th}$ and $60^{th}$ post-operative days whereas no significant difference was observed between immediate and $60^{th}$ post-operative days (P< 0.01) which was in accordance with Maiti *et. al.* (1999). Chandy (2000), Phaneendra *et. al.* (2016) and Kumar *et. al.* (2018). On the contrary, Daniella (2017) noticed a non-significant decrease in serum alkaline phosphatase levels from the initial base value upto 60 days post-surgery. The increase in levels of serum alkaline phosphatase was due to increased chondroblastic proliferation to cause bone formation during fracture repair and also maximum contribution was from the periosteum of destructed bone which was a rich source of serum alkaline phosphatase (Guyton, 1981, Hegade *et. al.*, 2007 and Mahendra *et. al.*, 2007). Nagaraja *et. al.* (2003) and Patil *et. al.* (2017) observed no significant variation in the serum alkaline phosphatase values.

To conclude, the growing bones in young dogs have thin cortex, lower strength and stiffness and the surgical technique employed for fracture stabilisation should consider these peculiarities in addition to preventing damage to growth plates and preservation of periosteum. Rigid internal fixation in growing young dogs might result in implant failure via screw pullout in addition to damaging the growing bones and growth plates. Hence, the method choosen for fracture stabilisation in young dogs should maintain a balance between implant-bone construct compliance and preventing damage to thin cortical bone. Elastic Plate Osteosynthesis with VCP using bridge plating principles offers these two advantages for its use in young dogs. The unique design of VCP (narrowness and thinness of the plate, cut to desired length, large number of holes per unit length, stacking of two VCPs) allows the placement of two or three screws in most proximal and distal holes leaving the central span of the plate over the fracture site unoccupied resulting in biological osteosynthesis even in proximal or distal fractures with shorter fragments. The two VCPs of same or different size could be stacked to increase the stiffness which was equal to the sum of the stiffness of each plate. The cortical screws were inserted without tapping to prevent screw pullout VCP provided good implant-bone compliance. In the present study, encouraging results were observed with early weight bearing, good limb usage and early clinical and radiographic union without any complications during Elastic Plate Osteosynthesis of radius and tibia fracture repair with VCP. The VCP was inexpensive which makes it suitable for use in veterinary practice together with excellent outcome.

# CHAPTER VI

# SUMMARY

The present study entitled "Plate osteosynthesis of long bone fractures using Veterinary Cuttable Plates in young dogs" was carried out with an objective to study the outcome of Elastic Plate Osteosynthesis for repair of long bone fractures in young dogs using Veterinary Cuttable Plates and was summarized as follows:

1. In the present study, out of 272 total number of fracture cases recorded, 246 (90.40%) were long bone fractures. Among the long bone fractures highest incidence was observed in femur (40.24%) followed by radius and ulna (26.83%), tibia and fibula (25.61%) and least in the humerus (7.32%).
2. Out of 129 fractures in radius and tibia incidence was more in adults aged >1 year (61.24%) than young dogs aged < 1 year (38.76%). Among 50 young dogs with radius and tibia fractures, incidence was more in males (58.0%) than in females (42.0%). Among different breeds presented, incidence was more in Mongrels (46.0%) followed by Pomeranian (18.0%), German Shepherd Dog (14.0%), Spitz (12.0%), Labrador Retriever (8.0%) and Dalmatian (2.0%).
3. Out of 50 radius and tibia fractures in young dogs 11 (22.0%) were proximal, 21 (42.0%) were diaphyseal and 18 (36.0%) were distal fractures. Among these 50

radius and tibia fractures in young dogs 34 (68.0%) were transverse fractures, 11 (22.0%) were oblique fractures, 4 (8.0%) were comminuted and 1 (2.0%) was spiral fracture.

4. Out of 6 cases of radius and tibia fractures included in the present study, the main etiological factor was fall from height (66.67%) followed by automobile accident (33.33%).
5. All six dogs presented for treatment either with radius or tibia fracture exhibited clinical signs like non-weight bearing of the affected limb, swelling, pain, crepitus and abnormal mobility with or without soft tissue damage.
6. Lateral and cranio-caudal radiographs taken were proved satisfactory in confirmatory diagnosis, identifying the location, classification of fracture and selection of appropriate size of plate.
7. Out of 6 cases included in the study, two cases were comminuted, slight overriding distal 3$^{rd}$ fracture of right radius and ulna designated as **2 2 B 2,** two cases were complete, midshaft, oblique, over riding tibio fibular fracture designated as **4 2 A 2,** one case was complete, oblique, overriding proximal 3$^{rd}$ fracture of left tibia and fibula designated as **4 2 A 2** and one case was complete, transverse, overriding proximal 3$^{rd}$ fracture of left tibia and fibula designated as **4 2 A 3** as per AO classification.
8. Premedication with atropine sulphate @ 0.04 mg/kg b.wt i.m. was administered 15 minutes prior to induction. Induction of anaesthesia with ketamine and midazolam @ 5mg/kg b.wt. and 0.2 mg/kg b.wt. respectively i.v. was satisfactory and facilitated easy intubation, followed by 2-3% isoflurane with 100% oxygen

provided satisfactory surgical plane of anaesthesia throughout the orthopaedic procedure with smooth and excitement free recovery.

9. Cranio-lateral and medial approaches used to expose the fractured radius and tibia shafts respectively were satisfactory and provided good exposure of fractured fragments and facilitated proper alignment, reduction of the fracture and application of plate.
10. The fractures were stabilised either with single VCP or stacked VCP based on body weight and size of the bone. In the present study, young dogs weighing less than 6 kg (Case no. 1 and 5) were stabilised with 2.0 mm Veterinary Cuttable Plate, young dogs weighing 6-10 kg (Case no. 3 and 4) were stabilised with 2.7 mm Veterinary Cuttable Plate Whereas young dogs weighing more than 10 kg (Case no. 2 and 6) were stabilised with stacked 2.0 mm VCP. The length of the plate required was decided by measuring the normal contralateral bone length in lateral view.
11. Post-operatively all the dogs were given inj. cefotaxime @ 22 mg/kg b.wt. i.m. s.i.d for one week and inj. meloxicam @ 0.2 mg/kg b.wt. i.m. s.i.d for 3 days. Modified Robert Jones bandage applied to the repaired limb provided good adjunct support to the internal fixation and helped in further stabilisation of the reduction. Wound dressing was done 3$^{rd}$ post-operative day and 10$^{th}$ post-operative day using 5% povidone iodine. The wounds healed without any complications in all the cases. Skin sutures were removed on 10$^{th}$ post-operative day.

12. All the animals in the study except case no. 4 showed early return to weight bearing and normal gait by 30$^{th}$ post-operative day which had mild gait abnormality.
13. Lateral and cranio-caudal radiographic views were taken on immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days for evaluation of fracture reduction, healing pattern and to assess the progress of fracture healing in all the cases. In case no. 1,3,4 and 5, clinical union observed on 15$^{th}$ post-operative day and complete radiographic union was observed in 30$^{th}$ post-operative day, whereas in case no. 2 and 5 clinical union occurred at 30$^{th}$ post-operative day and complete radiographic union on 60$^{th}$ post-operative day. The fractures healed by primary union in case no. 1, 3 and 4 and by secondary healing in case no. 2, 5 and 6.
14. Diaphyseal growth was undisturbed in all the cases and consistently occurred without loss of alignment or anatomical deformation of either epiphyses.
15. In the present study, at 60$^{th}$ post-operative day, all the animals were evaluated for limb usage and grouped as excellent, good, fair and poor. Out of 6 fractures treated 3 (50.00%) were excellent, 2 (33.33%) were good and 1 (16.67%) was fair. By 60$^{th}$ postoperative day, all the animals regained normal full functional limb except case no. 4 which still had occasional mild gait abnormality.
16. The implants were removed 5-8 weeks post-surgery after observing radiographic union of the fractures in all the cases under general anaesthesia.
17. In the present study blood was collected and serum separated on immediate, 15$^{th}$, 30$^{th}$ and 60$^{th}$ post-operative days for estimation of serum calcium, phosphorus and alkaline phosphatase in all the cases. Elevation in the serum calcium levels was

observed up to 15th post-operative day and reached a peak on 15th post-operative day with a gradual return to normal base value on 30th post-operative day. No statistically significant difference was observed between the time periods with regard to serum phosphorus levels. Elevation in the serum alkaline phosphatase levels was observed up to 15th postoperative day and reached a peak on 15th postoperative day with a gradual return to normal base value on 60th postoperative day.

To conclude, the growing bones in young dogs have thin cortex, lower strength and stiffness and the surgical technique selected should prevent damage to growth plates with preservation of periosteum. Rigid internal fixation during early stages results in catastrophic implant failure via screw pullout. The unique design of VCP (narrowness and thinness of the plate, cut to desired length, large number of holes per unit length, stacking of two VCPs) allows the placement of two or three screws in most proximal and distal holes leaving the central span of the plate over the fracture site unoccupied which mimics the biological osteosynthesis. The farther placement of screws away from fracture site increases the elasticity of the implant. These advantages along with good implant-bone construct compliance of VCP makes it suitable and advantageous for use in young growing dogs. In addition, VCP was inexpensive and the EPO technique using VCP was useful for long bone fractures in young dogs making it suitable for use in veterinary practice and the technique resulted in early weight bearing and good limb outcome without any complications.

## LITERATURE CITED

Aithal H P Singh G R and Bisht G S 1999 Fractures in dogs: A survey of 402 cases. Indian Journal of Veterinary Surgery 20(1): 15-21.

Balagopalan T P Devanand C B Rajankutty K Saradamma T Nayar S R Varkey C A Jalaluddin A M Nayar K N M and George P O 1995 Fractures in dogs-A review of 208 cases. Indian Journal of Veterinary Surgery 16(1): 41-43.

Bhatia A S Tank P H Vedpathak H S Karle A S and Desai B D 2010 Cadaveric canine tibial fractures and their stabilization with Ilizarov technique: An ideal training model. Indian Journal of Field Veterinarian 6 (2): 51-53.

Bruse S Dee J Prieur W D 1989 Internal fixation with a veterinary cuttable plate in small animals. Veterinary Comparative Orthopaedics and Traumatology 1: 40-46.

Bush B M 1991 Interpretation of laboratory results for small animal clinician. Blackwell Science Ltd, USA, 94-95.

Cabassu J P 2001 Elastic plate osteosynthesis of femoral shaft fractures in young dogs. Veterinary Comparative Orthopaedics and Traumatology 14: 40-45.

Chandy G 2000 Clinical evaluation of stainless steel and acrylic external skeletal fixators as adjuncts to intramedullary pinning for fracture of femur in dogs. M.V.Sc. thesis, Tamil Nadu Veterinary and Animal Sciences University, Chennai pp. 75.

Clark D M 1986 Treatment of open comminuted intra articular fractures of the proximal ulna in dogs. Journal of American Animal Hospital Association 23: 311-316.

Daniella S S 2017 Minimally invasive plate osteosynthesis (MIPO) for radius and tibia fracture stabilisation using limited contact dynamic compression plate in dogs. Thesis submitted to SVVU, Tirupati-517502.

Das B C Thilagar S Ayyappan S Justin William B Shafiuzama M and Arun Prasad A 2012 Surgical management of unstable diaphyseal tibial fracture with conventional Dynamic Compression Plating in dogs. IRJALS 1 (2): 36-48.

Dejardin L M and Cabassu J P 2008 Femoral fractures in young dogs. AO Dialogue 3: 39-43.

Denny R H and Butterworth S J 2000 Fracture Management. In A Guide to Canine and Feline Orthopaedic Surgery: 4th edition, Blackwell Science. Oxford, UK pp. 8586, 114-118, 501-502.

Dvorak M Necas A and Zatloukal J 2000 Complications of long bone fracture healing in dogs: functional and radiological criteria for their assessment. Acta Veterinaria Brno 69: 107-114.

Dwivedi D K Ganesh T N Ameerjan K and Geetha Ramesh 2009 Management of compound fracture of radius-ulna and tibia-fibula using Ilizarov's ring fixator in dogs. Indian Journal of Veterinary Surgery 30(2): 98-100.

Dyce K M Sack W O and Wencing C J G 1996 The hind limb of carnivores. Text book of Veterinary Anatomy 2nd edn: Saunders Philadelphia pp. 88-89.

Dymond N L Goldsmid S E and Simpson D J 2010 Tibial tuberosity advancement in 92 canine stifles: Initial results, clinical outcome and owner evaluation. Australian Veterinary Journal 88(10): 381-385.

Evans H E and Lahunta A D 2013 In: Miller's Anatomy of the Dog. 4th Ed Saunders Elsevier Missouri pp. 132-136.

Fazili M R Chawla S K Yadav K Tayal R and Behl S M 2005 Long bone fractures in dogs: A preliminary note. Haryana Veterinarian 44: 88.

Fruchter A M and Holmberg D L 1991 Mechanical analysis of the Veterinary Cuttable Plate. Veterinary Comparative Orthopedics and Traumatology 4: 116-119.

Gautier E 2009 A thorough understanding of the basic concepts of fixation, the bone biology and biomechanics, remains of outstanding importance- Bridge plating. AO Dialogue 2: 24-27.

Gentry S J Taylor R A Dee J F 1993 The use of veterinary cuttable plates: 21 cases. Journal of American Animal Hospital Association 29: 455–459.

Gomaa M Seddawy F E Behery A and Youssef W 2016 Different Modalities of Metacarpal Fracture Fixation in Mongrel Dogs: An Experimental Study. Advances in Animal and Veterinary Sciences 4(2): 107-113.

Guiot L P and Dejardin L M 2011 Prospective evaluation of minimally invasive plate osteosynthesis in 36 nonarticular tibial fractures in dogs and cats. Veterinary Surgery 40: 171-182.

Gupta P 2005 Use of interlocking nails for repair of humeral and tibial shaft fractures under image intensifier in dogs. M. V. Sc. thesis submitted to Anand Agricultural University, Anand, India.

Guyton A C 1981 Text book of medical physiology 6th edition, W.B Saunders Co, Philadelphia pp.259

Hammel S P Pluhar G E Novo R E Bourgeault C A and Wallace L J 2006 Fatigue analysis of plates used for fracture stabilization in small dogs and cats. Veterinary Surgery 35: 573-578.

Harasen G 2003 Common long bone fractures in small animal practice part1. The Canadian Veterinary Journal 44: 333-334.

Hari Krishna N V V 2013 Plate osteosynthesis of distal femoral fractures using locking reconstruction plate, locking distal femoral head plate and locking L-plates in dogs. Ph.D., thesis submitted to TANUVAS, Chennai.

Hegade Y Dilipkumar D and Ustarge S 2007 Comparative evaluation of biochemical parameters during fracture healing in dogs. Karnataka Journal of Agricultural Sciences 20: 694-695.

Hellyer P W Freeman L C and Hubbell J A E 1991 Induction of Anesthesia with Diazepam-Ketamine and Midazolam-Ketamine in Greyhounds. Veterinary Surgery 20(2): 143-147.

Heo S Y Lee K C and Lee H B 2012 Use of minimally invasive plate osteosynthesis for tibial diaphyseal fracture in three dogs. Journal of Veterinary Clinics 29(4): 339-343.

Jani S M Y Kushwaha R B Gupta A K Malik K and Soodan J S 2014 Occurrence of fractures in dogs: A retrospective study of five years. Indian Journal of Veterinary Surgery 35(1): 73-74.

Johnson A L Eurel J A C Losonsky J M and Egger E L 1998a Biomechanics and biology of fracture healing with external skeletal fixation. Compendium on Continuing Education for the Practicing Veterinarian 20(4): 487-489.

Johnson A L Smith C W and Schaffer D J 1998b Fragment reconstruction and bone plate fixation versus bridging plate fixation for treating highly comminuted femoral fractures in dogs: 35 cases (1987-1997). Journal of American Veterinary Medical Association 213(8): 1157 – 1161.

Johnson A L 2013 Fundamentals of Orthopedic Surgery and Fracture management. In Small Animal Surgery by Theresa Welch Fossum, 4$^{th}$ edition. Elsevier pp. 1033-1105.

Julie B 2005 Acrylic external skeletal fixator for the treatment of long bone fractures in dogs. M.V.Sc thesis, College of Veterinary and Animal Sciences, Mannuthy, Thrissur.

Kealy J K and McAllister H 2004 Bones and Joints. In Diagnostic Radiology and Ultrasonography of the Dog and Cat: 4th Edition, Elsevier Saunders pp. 299.

Kraus K H Toombs J P and Ness M G 2003 The practice of External Fixation. In External Fixation in Small Animal Practice: 1st edition, Blackwell Science Ltd, Oxford, UK pp. 5-98.

Kumar K M Prasad V D Lakshmi N D and Raju N K B 2018 Evaluation of biochemical parameters for assessment of fracture healing in dogs. The Pharma Innovation journal 7(3): 577-580.

Kushwaha R B Gupta A K Bhadwal M S Kumar S and Tripathi A K 2011 Incidence of fractures and their management in animals: a clinical study of 77 cases. Indian Journal of Veterinary Surgery 32(1): 54-56.

Langley-Hobbs S 2003 Biology and Radiological assessment of fracture healing. In Practice pp. 26-35.

Larsen L J Roush J K and McLaughlin R M 1999 Bone Plate Fixation of Distal Radius and Ulna Fractures in Small- and Miniature-Breed Dogs. Journal of the American Animal Hospital Association 35: 243-250.

Lidwell O M 1982 Infection following orthopedic surgery in conventional and unidirectional air flow operating theatres: The results of a prospective randomized study. Presented at the 49th Annual Meeting, American Academy of Orthopaedic Surgeons, New Orleans, LA.

Mahendra A M Ranganath L and Vasanth M S 2007 Effect of polymethylmethacrylate in femoral fracture repair on hemato-biochemical parameters in dogs. Indian Veterinary Journal 84: 587- 589.

Maiti B K Sen T B and Sanki S 1999 Haemato-biochemical changes following application of Ilizarov technique in treatment of femur fractures in dogs. Indian Journal of Animal Health 38: 133-134.

McCartney W Kiss K and Robertson I 2010 Treatment of distal radial-ulnar fractures in 17 toy breed dogs. Veterinary Record 166: 430-432.

McLain D L and Brown S G 1982 Fixation of Radius and Ulna Fractures in the Immature Dog and Cat: A Review of Popular Techniques and a Report of Eight Cases Using Plate Fixation. Veterinary Surgery 11(4): 140-145.

McLaughlin Jr R M Cockshutt J R and Kuzma A B 1992 Stacked veterinary cuttable plates for treatment of comminuted diaphyseal fractures in cats. Veterinary Comparative Orthopaedics and Traumatology 5: 22-25.

Miller M E Christensen G C and Evans H E 1964 Anatomy of the Dog. Philadelphia W B Saunders pp.371.

Miller C W Smith G S Sheridan C and Pennock P W 1998 Using unger system to classify 386 long bone fractures in dogs. Journal of Small Animal Practice 39: 390-393.

Milovancev M and Ralphs S C 2004 Radius-ulna fracture repair. Small Animal Practice 19:128-133.

Minto B W Prada T C Marinho P V T Zani C C and Menezes M P D 2015 Successful use of autogenous bone graft for the treatment of a radius-ulna nonunion in an amputee dog. Brazilian Journal of Veterinary and Animal Science 67(4): 979-983.

Mohindroo J Kumar A Singh N and Raghunath M 2006 Surgical management of bilateral femur fracture in a dog. Indian Veterinary Journal 83(12): 1302-1304.

Nagaraja B N Srinivas C L Jayadevappa S M Ranganath B N and Vijayasarathy S K 2003 Biochemical and histopathological changes in dogs with femoral fractures immobilized with plastic rods. Indian Journal of Veterinary Surgery 24 (2): 111-112.

Newton C D and Nunamaker D M 1995 Fractures of tibia and fibula. In text book of small animal orthopaedics: JB Lippincott, Philadelphia pp. 439-444.

Nithin C J 2016 Studies on anaesthetic sparing effect of butorphanol-acepromazine-atropine and tramadol-acepromazine-atropine premedication on induction and maintenance anaesthetic protocols for Orthopaedic Surgeries in dogs. Thesis submitted to SVVU, Tirupati-517502.

Patil M Dilipkumar D Shivaprakash B V Kasaralikar V R Tikare V P and Ramesh B K 2017 Physiological and haemato-biochemical changes during repair of femur fracture in dogs. The Pharma Innovation Journal 6(8): 381-385.

Peirone B Camuzzi D and Filippi D 2002 Femoral and humeral fracture treatment with an intramedullary pin/ external fixator tie-in technique configuration in growing dogs and cats. Veterinary Comparative Orthopaedics and Traumatology 15: 85–91.

Peirone B Rovesti G L Baroncelli A B and Piras L 2012 Minimally Invasive Plate Osteosynthesis Fracture reduction techniques in small animals. Veterinary Clinics of North America Small Animal Practice 42: 873-895.

Penwick C R 1985 Pre-operative Patient Preparation. In Textbook of Small Animal Orthopaedics. Lippincott Company, Philadelphia.

Phaneendra M S S V Lakshmi N D Prasad V D and Raju N K B 2016 Evaluation of biochemical parameters for assessment of fracture healing in dogs. Journal of Livestock Science 7: 111-113.

Piermattei D L 1993 Approach to shaft of tibia. In atlas of surgical approaches to the bones and joints of the dog and cat 3rd edition, W.B. Saunders company, Philadelphia pp. 298.

Piermattei D L Flo G L and DeCamp C E 2006 Fractures: Classification, diagnosis and treatment. In Handbook of Small Animal Orthopaedics and Fracture Repair, Volume 1, St. Louis (MO): Saunders Elsevier pp. 25-159.

Piermattei D L and Johnson A K 2004 The Forelimb. In An Atlas of Surgical Approaches to the Bones and Joints of the Dog and Cat. 4th edition. Saunders Elsevier, Philadelphia pp. 246-253.

Piras A 2000 Fractures in skeletally immature dogs. Okland Small Animal Veterinary Clinic Referral Northern Ireland UK.

Piras L Cappellari F Peirone B and Ferretti A 2011 Treatment of fractures of the distal radius and ulna in toy breed dogs with circular external skeletal fixation: a retrospective study. Veterinary Comparative Orthopaedics and Traumatology 3: 1-8.

Pozzi A Hudson C C Gauthier C M and Lewis D D 2013 Retrospective comparison of minimally invasive plate osteosynthesis and open reduction and internal fixation of radius-ulna fractures in dogs. Veterinary Surgery 42: 19-27.

Pozzi A and Lewis D D 2009 Surgical approaches for Minimally Invasive Plate Osteosynthesis in dogs. Veterinary Comparative Orthopaedics and Traumatology 22(4): 316-320.

Rahal S C Mamprim M J Caporali E H G and Teixeira C R 2003 Osteomyelitis associated with an orthopedic implant. Canadian Veterinary Journal 44: 597-599.

Ramesh Chandra T S 2016 Femur shaft fracture stabilisation using intramedullary pinning and stack pinning in dogs. Thesis submitted to SVVU, Tirupati-517502.

Ramirez J M and Macias C 2016 Conventional bone plate fixation of distal radius and ulna fractures in toy breed dogs. Australian Veterinary Journal 94(3): 76–80.

Ranpariya J J Barvalia D R Padaliya N R and Javia C B 2013 Safety and efficacy of Butorphanol-Acepromazine-Glycopyrrolate as premedicant combination to midazolam-ketamine induction and isoflurane maintenance in canine orthopaedic surgery. Indian Journal of Field Veterinarians 9(1): 30-34.

Rao J R Kumar V G Rao T M Kumar D P and Reddy K C S 2017 Management of radius-ulna and tibial diaphyseal fractures with type IIa external skeletal fixation in dogs. The Pharma Innovation Journal 6(8): 372-376.

Reems M R Beale B S and Hulse D A 2003 Use of a plate-rod construct and principles of biological osteosynthesis for repair of diaphyseal fractures in dogs and cats: 47 cases (1994–2001). Journal of American Veterinary Medicine Association 223(3): 330–335.

Rhangani A T 2014 Incidence, classification and management of appendicular bone fractures in dogs in Nairobi County, Kenya. A retrospective study. Doctoral dissertation, University of Nairobi pp. 22-31.

Roush J K and McLaughlin R M 1998 Fundamentals of fracture management. Veterinary Medicine 93: 1065-1070.

Sarrau S Meige F and Autefage A 2007 Treatment of femoral and tibial fractures in puppies by elastic plate osteosynthesis – a review of 17 cases. Veterinary Comparative Orthopaedic Traumatology 20(1): 51-58.

Schmokel H G Stein S Radke H Hurter K and Schawalder P 2007 Treatment of tibial fractures with plates using Minimally Invasive Percutaneous Osteosynthesis in dogs and cats. Journal of Small Animal Practice 48: 157-160.

Shales C 2008 Fracture management in small animal practice 1.Triage and stabilization. In Practice 30: 314-320.

Siemens M G 1970 Calcium inorganic phosphorus and magnesium metabolism in health and in diseases in clinical biochemistry of domestic animals 2nd edition. C.E. Academic press, New York 922-923.

Singh A P Mirakhur K K and Nigam J M 1983 A study on the incidence and anatomical locations of fractures in canine, caprine, bovine, equine and camel. Indian Journal of Veterinary Surgery 4(1): 61-66.

Singh C K Sarma K K Kalita D Deuri B and Nath P J 2017 Review on Fracture, Dislocation and Neurological Affections in Animals between April 2011 to March 2013 around the Urban and Suburban Area of Guwahati, India. International Journal of Current Microbiology and Applied Sciences 6(7): 1540-1550.

Singh M Nigam J M Sharma S K Varshney A C and Kumar V 1999 Incidence of fracture in canines and their management. Indian Veterinary Journal 76: 922-923.

Sturmer K M 1996 Elastic plate osteosynthesis, its biomechanics, indications and technique in comparison with rigid internal fixation. Der Unfallchirurg 99: 816-829.

Tambe N Y Patel T P Mistry J N Patel P B and Patel J B 2012 Retrospective study on the incidence of fractures in animals. Intas Polivet 13(2): 364-366.

Tan S L E and Balogh Z J 2009 Indications and limitations of locked plating. Injury 40 (7): 683-691.

Theoret M C and Moens N M M 2007 The use of veterinary cuttable plates for carpal and tarsal arthrodesis in small dogs and cats. Canadian Veterinary Journal 48: 165-168.

Thilagar S and Balasubramanian N N 1988 A retrospective study on the incidence and anatomical location in 204 cases of fractures in dogs. Cheiron 17(2): 68-71.

Thurmon J C Tranquilli W J Benson G J 1996 Preanaesthetics and anaesthetics adjuncts. In Textbook of Veterinary Anaesthesia by Lumb and Jones 3rd Ed. Baltimore pp. 183-185.

Tobias T A 1995 Slings, padded bandages, splinted bandages and casts. In Small Animal Orthopaedics, Mosby 97-98.

Uma Rani R Rajendran N and Vairavasamy K 2012 Immobilisation and treatment of femoral diaphyseal oblique fractures in dogs using double intramedullary pinning and cerclage wiring - A study in twelve patients. Intas Polivet 13(2): 411-415.

Uma Rani R Vairavasamy K and Kathiresan D 2004 A Retrospective study on bone fractures in canines. Indian Veterinary Journal 81: 1048-1050.

Unger M Montavon P M and Heim U F A 1990 Classification of fractures of long bones in the dog and cat: Introduction and clinical application. Veterinary Comparative Orthopaedics and Traumatology 3: 41-50.

Vaughan L C 1963 A clinical study of Non-union fractures in the dog. Journal of Small Animal Practice 5:173 -177

Zahn K Frei R Wunderle D Linke B Schwieger K Guerguiev B Pohler O and Matis U 2008 Mechanical properties of 18 different AO bone plates and the clamp-rod internal fixation system tested on a gap model construct. Veterinary Comparative Orthopaedics and Traumatology 21(3): 185-194.