# Anatomically Contoured Intramedullary Interlocking Nailing for Fixation of Femoral Fractures in Dogs

**THESIS**

By


**Sakshi**
(V-2017-30-031)


Submitted to

**CHAUDHARY SARWAN KUMAR**

**HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA**

**PALAMPUR-176062, INDIA**

in
Partial fulfillment of the requirements for the degree
of

**MASTER OF VETERINARY SCIENCE**

**(VETERINARY SURGERY AND RADIOLOGY)**

**2019**

**Dr. SP Tyagi**
(Professor)

Department of Veterinary Surgery and Radiology
DGCN College of Veterinary and Animal Sciences
CSK Himachal Pradesh Krishi Vishvavidyalaya
Palampur (H.P.) India-176 062

# CERTIFICATE-I

This is to certify that the thesis entitled, "**Anatomically contoured intramedullary interlocking nailing for fixation of femoral Fractures in dogs**" submitted in partial fulfillment of the requirements for the award of the degree of **Master of Veterinary Science** in the discipline of **Veterinary Surgery and Radiology** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Sakshi (V-2017-30-031)** daughter of **Sh. Ravinder Singh** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

**Dr. SP Tyagi**
Major Advisor

Place: Palampur
Date:

## CERTIFICATE-II

This is to certify that the thesis entitled, "**Anatomically contoured intramedullary interlocking nailing for fixation of femoral Fractures in dogs**" submitted by **Sakshi (V-2017-30-031)** daughter of **Sh. Ravinder Singh** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Veterinary Science** in the discipline of **Veterinary Surgery and Radiology** has been approved by the advisory Committee after an oral examination of the student in collaboration with an External Examiner.

| | |
|---|---|
| Dr. SP Tyagi<br>Chairperson | Dr. Ajay Gupta<br>External Examiner |

Advisory Committee

| | |
|---|---|
| Dr. Adarsh Kumar<br>Member | Dr. Amit Kumar<br>Member |
| Dr. Ankur Sharma<br>Member | Dr. Madhumeet Singh<br>Dean PG Nominee |

**Head of the Department**

**Dean, Postgraduate Studies**

# ACKNOWLEDGEMENTS

First and foremost, I would like to thank God Almighty for giving me strength, knowledge and ability to understand this research study and to persevere it and complete it satisfactorily.

I express my profound sense of gratitude and sincere regards to my advisor, **Dr. SP Tyagi,** Professor, Department of Veterinary Surgery and Radiology for his valuable guidance, relentless efforts, constant encouragement, constructive suggestions and inspirational attitude, without which this work would not have been possible.

I feel overwhelmed in extending my heartfelt thanks and respect to **Dr. Amit Kumar**, Assistant Professor, Department of Veterinary Surgery and Radiology, who has been by my side, guiding, supporting and encouraging me during my work. His constant support and guidance during the thesis writing had helped me accomplishing this task. I will always remain indebted to him for his untiring efforts in successful completion of my thesis.

I convey my thanks to **Dr. Adarsh Kumar**, Professor and Head, Department of Veterinary Surgery and Radiology, for his consistent help and co-operation. I will remain thankful to Dr. R.K. Agnihotri, Dean, Post Graduate studies for his academic help and support.

I am especially thankful to **Dr. Sukhpreet Singh** for his valuable help during my work. I am thankful to my seniors Dr. Divya Sharma, Dr. Manisha Thakur, Dr. Rohit Bhat, Dr. Davinder Saini and Dr. Adrian Camara for their help at different stages of my life. At the same time, I can't overlook the significant contributions of Dr. Arvind, Dr. Murtaza, Dr. Kanika, Dr. Mansi, Dr. Anjali, Dr. Sukti, Dr. Deepshika, Dr. Mohit, Dr. Ankit, Dr. Prince, Dr. Manish and Dr. Amit Karmani for their generosity, friendship and timely assistance.

My thanks are due to Mr. Virender, Mr. Prem, Mr. Narendar and Mr. Ravikant who took care of all the logistics necessary for my research work.

I would give thanks to my clients for their support and compliance during this period. More particularly let me thank our four-footed friends for their utmost contribution to this text.

I wish to record personal reckoning of gratitude to my major milepost: **My Parents** for their unstinting support, prayers and belief in me. Words fail me in my efforts to articulate my gratitude for all that they have done for me.

(Sakshi)

Place: Palampur

Date:

# Table of Contents

| List Of Abbreviations | |
|---|---|
| % | Percent |
| ± | Plus-minus |
| ACIILN | Anatomically contoured intramedullary interlocking nail/nailing |
| ALT | Alanine transaminase |
| AST | Aspartate transaminase |
| BUN | Blood urea nitrogen |
| CMM | Conjunctival mucous membrane |
| CSKHPAU | Chaudhary Sarwan Kumar Himachal Pradesh Agricultural university |
| DLC | Differential leucocyte count |
| DGCNCOVAS | Dr. G.C. Negi College of Veterinary and Animal sciences |
| et al. | et alia (and others) |
| ETP | End threaded pinning |
| FAS | Fracture assessment score |
| Fig. | Figure |
| FRD | Final reappraisal day |
| Hb | Haemoglobin |
| i.e. | id est  (that is) |
| IFD | Internal fixation day |
| IILN | Intramedullary interlocking nail/nailing |
| Inj. | Injection |
| Kgs | Kilograms |
| OPD | Outdoor patient department |
| Min | Minutes |
| Mm | Millimetre |
| No. | Number |
| PCV | Packed cell volume |
| STT | Skin tenting time |
| TIF | Trauma to internal fixation |
| TEC | Total erythrocyte count |
| TLC | Total leucocyte count |
| TVCC | Teaching veterinary clinical complex |

## List Of Tables

# List of figures

**Department of Veterinary Surgery and Radiology**
**CSK Himachal Pradesh Krishi Vishvavidyalaya**
**Palampur- 176062**

| | |
|---|---|
| Title of the thesis: | Anatomically contoured intramedullary interlocking nailing for fixation of femoral Fractures in dogs |
| Name of the student: | Sakshi |
| Admission number: | V-2017-30-031 |
| Major discipline: | Veterinary Surgery and Radiology |
| Minor discipline: | Veterinary Medicine |
| Date of thesis submission: | 23/7/2019 |
| Total pages of the thesis: | 73 |
| Major Advisor: | Dr. SP Tyagi |

## ABSTRACT

The study was conducted on the clinical cases of dogs presented in the department of Veterinary Surgery and Radiology, DGCNCOVAS, CSKHPKV, Palampur from January 2018 to April 2019. The main objectives were to evaluate the clinical application of specially designed anatomically contoured interlocking nails (ACIILN) for repair of femoral fractures in dogs and to compare it with other fixation techniques in similar kinds of fractures. Besides, a brief study was also undertaken to record the regional occurrence of fractures in dogs. The dogs formed the majority of fracture cases presented to the department (204 out of 262). The distribution of fractures in them was found to be 78 per cent and the incidence as 16 per cent with juveniles forming the majority among them (105 out of 204). The automobile accident was the main etiology for fractures in dogs (96 out of 204) followed by fall from a height (55 out of 204) and the femur, most affected among long bone (53 out of 145). All the femoral fractures in dogs were closed; the fracture types varied a lot and were repaired with different fixation techniques. ACIILN technique was utilized to fix 10 selected cases of simple diaphyseal femoral fractures in these dogs. The technique was later compared with only end threaded self-tapping pinning (ETP) in three selected comparable cases of mid-diaphyseal fractures.The ACIILN technique was almost similar to straight IILN techniques. However, difficulty was faced during drilling of distal holes to align with cannulation of ACIILN. Frequent misalignment of distal screws occurred, particularly at the most distal level. It was due to the sloping anatomy of distal femur leading to slipping of drill bits a little despite use of appropriate drill sleeves. It resulted in causing an eccentric hole and hence screws often missed the ACIILN cannulation. However, at least one screw could still be fixed properly in either segment of fractures in all cases and the fractures largely remained stable leading to uneventful healing in most cases. However, technically, it was more cumbersome, time-consuming and challenging as compared to ETP technique. Adequate intramedullary reaming of distal femurs by straight reamers was another common difficulty during application of ACIILN.

| | |
|---|---|
| Sakshi | Dr. SP Tyagi |
| Student | (Major Advisor) |

Head of the Department

**Chapter 1**

# Introduction

Femur is the most common fractured long bones in dogs. These fractures are usually the result of major trauma, but they can also be caused by disease of bone itself. Most femur fractures remain closed because surrounding musculature prevents the fractured fragments to protrude through them. The femoral fracture cannot be managed by simpler methods of closed reduction and external coaptation such as casts or splints and therefore, internal fixation is necessary to fix them. The primary techniques for fixation of long bone fractures are intramedullary pinning/nailing, cross-pinning, intramedullary interlocking nailing (IILN), external skeletal fixation and bone plating. Whereas, auxiliary methods like orthopaedic wiring and lag screw are also used in conjunction with primary techniques. These techniques have their own merits and demerits such as breakage of implant, migration, bending, loosening, bone rotation, delayed union and malunion. Many factors affect the selection of a technique for a specific situation. The type and location of the fracture, age of patient, temperament of patient, and extent of soft tissue injury may direct the selection of one approach over another.

The ideal fracture fixation technique is the one that adequately immobilize the fracture until healing and also provides sufficient flexibility at the fracture site to promote early limb functioning by formation of external bridging callus.

From the biomechanical point of view, the fracture fixation device is strongest when it follows the central axis of bone, to counter the bending forces (e.g., medio-lateral versus cranio-caudal). An intramedullary device follows the central axis of bone, so effectively counters the bending forces as compared to bone plating where implant goes away from the central axis of bone. The IILN screws counteract axial loading forces responsible for fracture collapse, shortening of the bone, and migration of nail into soft tissues. Furthermore, interlocking screws prevent rotation at the fracture site.

The intramedullary pin is mostly used in the treatment of femur fracture in dogs, because of its speed of insertion, minimal exposure of fracture site, low cost, requirement of less expertise and equipment, while its primary disadvantage is that it cannot resist rotational forces adequately.

Intramedullary interlocking nailing (IILN) evolved as a modification of intramedullary nailing over the years for dealing with such constraints. Beginning in 1970, Klemm devised implants based on conventional open section nails with holes for bone screws. His contemporaries, Grosse and Kempf worked to make their own interlocking nails. By 1984, interlocking nailing of the femur and tibia was an accepted procedure in North-America (Rommens and Hessmann, 2015). Huckstep originally developed modified interlocking nail for humans. Johnson and Huckstep successfully used these nails in dogs in 1986.

Over the years, various types of new IILN nails such as titanium alloy nails and retrograde supracondylar intramedullary nails e.g. GSH (Green-Seligson-Henry) nail have been introduced. The use of GSH nail implant is indicated in the management of distal comminuted non-articular fractures and fractures with intra-articular extension (Henry et al., 1991). In addition, slotted clover leaf sectional designs were being replaced by non-slotted designs that provide greater rotational stability.

The indications for IILN in canines are primarily for different types of diaphyseal fractures in long bones but these can also be sometimes used for fixing even metaphyseal fractures. This device has also been used for stabilization of corrective osteotomies, intercalary cortical allografts, and revision of failed fixations (Slatter DH, 2003). Internal lengthening nail (ILN) is a recent development in limb lengthening and deformity correction specialty (Muthusamy et al. 2016).

Various methods of internal fixation of femoral fractures in dogs above are being utilized in the department of Veterinary Surgery and Radiology, DGCNCOVAS Palampur, the technique of IILN has also been evaluated. In such studies, it was observed, that the conventionally used interlocking nails were straight in shape but the diaphysis of dogs were curved with convex surface facing cranially. Besides, the femoral shaft of mature dog tapers to mid-shaft isthmus and then flares to distal metaphysis. Hence, it was difficult to place straight intramedullary implants in such a curved distal segment of femoral bones without compromising the anatomical alignment of fragments.

Therefore, it was hypothesized that an appropriately designed angled or anatomically contoured interlocking nails (AC IILN) could be placed more easily in dog's femur and could maintain the anatomical alignment of its fractured fragments in a better manner. Thus, the present study was proposed to evaluate AC IILN in different types of femoral fractures of dogs and to compare it with other fracture fixation techniques.

The primary objectives of this study were as follows:

1. Clinical application of anatomically contoured intramedullary interlocking nailing technique for stabilization of femoral fractures in dog.

2. Comparative evaluation of different techniques for fixation of femur fractures in dogs.

**Chapter 2**

# Review of literature

The available literature has been reviewed under the following headings:

**2.1** Study of occurrence of fractures in dogs

**2.2** Intramedullary interlocking nailing for fixation of fractures in dogs

**2.3** Intramedullary interlocking nailing with modified nails and other techniques for fixation of fractures in dogs

## 2.1: Study of occurrence of fractures in dogs:

Simon et al. (2010) did a survey to analyze pelvic limb fractures in dogs reported to Radiology Unit of the Madras Veterinary College, from April 2007-May 2009. A total 478 cases of pelvic limb fractures were reported in this study. The incidence was highest in young animals (46.02 percent) less than six months of age. Majority of the fractures were recorded in non-descript dogs (47.48 percent). Male dogs were affected more (61.5 percent) than female dogs of all the age groups. Among the various bones of the pelvic limb the incidence was highest in femur (47.48 percent) followed by tibia and fibula (42.67 percent). The occurrence of oblique/transverse fractures were more (44.8 percent) than comminuted (26.8 percent) and avulsion fractures (7.53 percent).

Kushwaha et al. (2011) recorded fractures in 77 animals out of 1050 surgical cases with an overall incidence of 7.33%. The species wise incidence was maximum in dogs (37; 3.52%) followed by cows (15; 1.43%), buffaloes, horses and goats (7; 0.67% each), birds (2; 0.19%), and camels and sheep (1; 0.095% each). Overall, fractures were highest in femur (37.04%), followed by tibia (24.70%). In dogs, fractures were highest in femur (65%), followed by radius-ulna and tibia (12.50% each), and humerus (10%).

Ben Ali (2013) conducted a study on the incidence of different types of fractures in dogs and cats. Total of 116 cases (88 dogs and 28 cats) were studied and it was found that the occurrence of femur fractures in dogs were 37.5% while in cats it was 25%, tibial fractures were 21.5% and 10%, humerus fractures were 7.9% and 14%, radius and ulna were 19 and 14%, pelvic bone fractures were 6.8% and 21% respectively.

Minar et al. (2013) retrospectively studied eighty cases in dogs showing-bone fractures from January, 2005 to December, 2011. Fractures were mainly observed in miniature dogs such as Yorkshire terrier (12%), Poodle (12%), and Maltese (9%). Fracture incidence was higher in male dogs (54%) than female dogs (46%). Hind limb fracture (37%) was the most common. Distribution of limb fractures was higher in the femur (19), followed by the tibia/fibula (15), radius/ulna (13), humerus (11), and mandible (8). Pelvic fracture was observed in 19 cases. Fractures were mainly caused by traffic accidents (43%), whereas 28.5% of fractures were due to falling down.

Elzomor et al. (2014) conducted a study on 227 cases of dogs and cats suffering from fracture (125 dogs and 102 cats) and reported the occurrence of pelvic limb fractures in 50.60 percent cases in dogs and 69.39 percent cases in cats. Femoral fracture in dogs constituted 56.80 and in cats 59.80 percent of pelvic limb fractures. The highest proportion of femoral fracture in dogs was mid-shaft fracture (46.10 %), while in cats it was the supracondylar fracture (57.41%).

Sran et al. (2016) recorded 571 long bone fractures in dogs over a period of 22 months, accounting for an incidence of 6.47 per cent among surgical cases with an overall incidence of 1.60 per cent. Among long bones, the most commonly fractured bone was femur (44.48%), followed by radius/ulna (23.12%), tibia/fibula (21.19%) and humerus (11.21%). Fracture distribution was more in male dogs (68.65%) than females (31.35%). Dogs in the age group of 6-12 months showed the highest occurrence (21.89%), followed by 3-6 months (20.49%), 1-2 years (16.64%), 0-3 months (14.71%), 2-4 years (14.54%) and >4 years (11.73%). Automobile accident was recorded as the major cause of fracture (56.39%) followed by fall from height (26.97%), unknown trauma (9.28%), injury while running (2.45%), abusive (2.10%), injury by animals (1.58%) and cage injury (1.23%).

Kumar (2016) studied the basic epidemiological data of fractures in animals and reported that highest distribution of fractures in dogs (64.11%), followed by bovines (23.52%), equine (8.23%) and other (4.11%). Juvenile dogs suffered more from fractures (67.88%), however in bovines and equines more number of adults were affected. Femur was most commonly fractured long bone (33.02%) in dogs.

Kaur (2017) also reported that among different animals, dog formed a significant majority for fracture cases (72.56%). In dogs, fractures were reported to be more common in males (69.74%) and juvenile age-group (62.18%).

Libardoni et al. (2018) retrospectively evaluated the frequency of femur fractures in dogs and cats. Sixty-two femoral fractures were evaluated. A total of 61 animals, 50 (82.0%) dogs and 11 (18.0%) cats, had femoral fractures that were submitted to osteosynthesis. Intramedullary pins were used in association with cerclage and tension band for osteosynthesis in proximal fractures. In diaphyseal fractures, bone plates and screws, two intramedullary pins (insulated or with cerclage) and Tie-In configuration were used. In distal fractures, modified Rush intramedullary pins, cross pins and Tie-In configuration were used.

**2.2: Intramedullary interlocking nailing for fixation of fractures in dogs:**

Muir et al. (1993) stabilized closed comminuted diaphyseal tibial fracture in an adult dog with a custom made interlocking intramedullary nail. The fracture progressed to union by 14 weeks, by secondary bone healing.

Georgiadis GM et al. (1990) studied the dynamization of statically locked tibial nails in a canine model. Reamed static interlocking nails were inserted in 16 canine tibiae with unstable osteotomies. At 8 weeks, half were dynamized. At 20 weeks, the tibiae were harvested and studied radiographically, biomechanically, and histologically. Apparent clinical union was present in all tibiae. Complete radiographic bony union was achieved in 13 of 16, with residual radiolucent lines in two tibiae in the static and one in the dynamic group. Biomechanically, dynamization improved stiffness at the fracture site. Histological patterns were similar, but there were trends toward a denser trabecular callus pattern in the dynamized group. The results of this animal study indicate that although dynamization may have a beneficial effect on the quality of early bony healing.

Dueland et al. (1996) studied the structural properties of interlocking nails in canine femur. It was concluded that intramedullary nail with 6mm diameter was less stiff to bending and torsion than 8mm diameter intramedullary nail. Therefore it was preferable to use the larger 8mm intramedullary nail clinically wherever possible.

Durall and Diaz (1996) used static locking nailing to repair fractures of femoral diaphysis in 15 dogs. Good limb function was obtained after less than 3 weeks in 12 dogs. Radiographic examination revealed fracture healing in 11 of the dogs, between 8 and 16 weeks after surgery. One dog was not returned for follow up until 22 weeks after surgery, the remaining 3 dogs had to have additional operations one because of the loosening of the screw, one because of non-union and one because of sequestrum formation.

Muir and Johnson (1996) re-stabilized the comminuted femoral fracture in a dog with interlocking intramedullary nail. Previously femoral fracture was stabilized with intramedullary pin and cerclage wire. The fracture was unstable, the intramedullary pin protruded through the skin over the hip, and Staphylococcus spp. was isolated from the fracture site. The loose pin was removed, and the fracture was re-stabilized with a 6.0-mm and 3 interlocking screws. Cephalexin was given orally for 6 weeks. Eight weeks after the second surgery, the fracture was healed radiographically. Seventeen months later, the dog had a persistent mild lameness that was associated with low-grade osteomyelitis. The lameness resolved after the implants were removed, and antibiotics were administered.

Endo et al. (1998) developed an intramedullary interlocking nail method for femoral and tibial fracture for the treatment of dogs and cats with different fracture configuration and conclude that the animals were able to bear weight on the treated leg within three days and prognosis was excellent. The study revealed that newly devised interlocking nail was found to be effective in small animals. The fractured bones were reduced and fixed without shortening or rotative malformation of the legs even when they were comminuted and the authors have removed the implant to avoid stress shielding.

Roush and Mclaughlinn (1999) opined the fact that interlocking nailing was useful alternative to external fixation and plates for long bone fractures. The study indicated their primary use for the stabilization of the diaphyseal fractures of the long bones in small, medium and large dogs having fracture configuration of transverse, oblique or comminuted but not involving the metaphyseal region of the bone.

Bernarde et al (2001) studied in vitro biomechanical study of bone plate and interlocking nail in a canine diaphyseal femoral fracture model. Bone specimens were divided into 2 groups (10 femurs each). Left femurs were stabilized with a DCP and 8 bi-cortical screws; right femurs were stabilized with an IILN and 3 screws. The testing was first conducted nondestructively and then until breakage. Structural properties, i.e., stiffness, yield limits, and failure limits, were determined. Interfragmentary motion was measured during nondestructive tests with the use of an optoelectronic device. It was concluded that structural properties and interfragmentary shear motion analysis demonstrated a much higher rigidity in the IILN-bone than in the DCP-bone constructs.

Moses et al. (2002) conducted a multi-centric study for placement of interlocking nails in humerus fractures of dogs and cats. It was suggested that a single transcortical screw is placed proximally; the screw should be distal or caudal to the tricipital line in order to engage sufficient cortical bone. Eighteen (86%) fractures healed when stabilized with intramedullary interlocking nails. Three fractures did not heal. One was in a dog where a pathological fracture was temporarily stabilized with an intramedullary interlocking nail, one in a dog that died of an abdominal crisis three weeks after surgery and one in a dog in which fracture stabilization collapsed due to incorrect implant selection. It was concluded that intramedullary interlocking nails are well suited to the stabilization of humeral diaphyseal fractures in dogs and cats.

Raghunath (2002) conducted a study on 44 dogs comparing the role of intramedullary interlocking nailing, dynamic compression plating and single intramedullary pinning in long bone fracture fixation. It was concluded that static intramedullary interlocking nailing provided satisfactory stability and quick rehabilitation of limb resulting in high success rate and less postoperative complications.

Duhautois et al. (2003) studied 121 cases (78 dogs and 43 cats) for use of veterinary interlocking nails for diaphyseal fractures of femur, tibia and humerus in dogs and cats. Interlocking nailing was used in static (n=106) and dynamic (n=15) fixation mode. Cerclage wire was also used in 63 cases. The functional outcome evaluated and fracture healing was quantified after 6 weeks and 3 months. It was concluded the high healing rate and low complications associated even with unstable fractures.

Singh et al. (2007) repaired 3 bilateral femur fractures in dogs and concluded that static intramedullary interlocking nailing could be successfully used to manage the highly unstable and complex bilateral femoral fractures resulting in early weight bearing and quick rehabilitation with high success and low complication rates.

Raghunath and Singh (2008) used intramedullary interlocking nailing for stabilization of diaphyseal fractures of humerus, femur and tibia in 17 clinical cases of dogs and results suggested that IILN could provide good fracture reduction and stability in a wide range of fractures with low complication rates.

Asif et al. (2011) studied the clinical evaluation of static and dynamic intramedullary interlocking nailing technique for femoral fracture repair in dogs. The study was conducted on 24 clinical cases of dogs with diaphyseal femoral fracture. Bony union with negligible periosteal callus and early bone remodeling was the findings in static method and bony union with large periosteal callus with dynamic IILN stabilization.

Burns et al. (2011) determined the fatigue properties of an interlocking nail (ILN) influenced by metaphyseal or diaphyseal location of the locking bolt in 19 pairs of canine femur. Metaphyseal bolts failed at higher axial loads than diaphyseal bolts, with bolt failure because of bending at the nail-bolt interface. All of the metaphyseal bolt constructs survived torsional testing whereas 9 of 10 diaphyseal bolt constructs failed catastrophically because of spiral fracture through the adjacent cortical bone. It was concluded that Placement of a locking bolt in metaphyseal bone extends fatigue life under axial loading and decreases the incidence of catastrophic failure under torsional loading.

Igna et al. (2011) performed interlocking nail stabilization of diaphyseal long-bone fractures in dogs and cats. Femoral fractures in 3 dogs and 3cats were repaired. Two of the fractures were comminuted. Clinical outcome was excellent in all cases. The six cases were x-ray evaluated at 60 days after surgery and healed without complication. The high success rate associated with a functional outcome suggests that ILN can be used to stabilize diaphyseal fractures in dogs and cats.

Hansda et al. (2012) did comparative evaluation of Steinmann pin, Kuntscher nail and intramedullary interlocking nailing in femoral fractures of canines. Eighteen femur fractures were treated and evaluated for 60 days post operatively. It was found that animals treated with intramedullary interlocking nailing required less time for weight bearing and fracture healed with lesser amount of callus and complications with quick rehabilitation.

Raghunath et al. (2012) studied the management of segmental fractures of tibia and femur by static intramedullary interlocking nailing in 12 dogs. Use of intramedullary interlocking pinning results in preservation of more periosteal vascularity, promoting biological osteosynthesis. For femur repaired by interlocking nails, the distal fracture united 3 weeks to 3 months earlier than the proximal one.

Kumar (2016) did the comparative evaluation of straight intramedullary interlocking nail (ILN), End threaded Steinmann pinning (ETP)and plain Steinmann pinning (SP) for fixation of femoral fractures in dogs. It was reported that ILN could be used successfully for fixation of uncomplicated diaphyseal fractures of femur in dogs. Status of fracture fixation was superior with IILN group in comparison to ETP and SP groups. Occasional inadvertent penetration of distal femoral cortex was found with all the three techniques used.

Arican et al. (2017) repaired twenty-six dogs having different body weights with diaphyseal fractures of the femur, tibia or humerus. The dogs were followed up for 6 months. There were 10 femoral fractures, 12 tibial fractures and 4 humeral fractures. Three ILN lengths with three different diameters (4, 6 and 8 mm) were used. Each ILN had a trocar tip on one end and four screw holes (two distal and two proximal). Nine (39.1%) patients had aseptic nonunion and malunion fractures. A static fixation mode was used for nine fractures and a dynamic fixation mode was used in 17 (65.3%). At 6 months, the functional outcome was excellent in 15 (57.6%) animals, good in seven (26.9%), fair in three (11.5%), and poor in one (3.8). In conclusion, the use of ILNs to repair diaphyseal fractures of the femur, tibia, and humerus in dogs resulted in a good or excellent functional outcome in most patients.

Kaur (2017) evaluated the interlocking nailing technique for fixation of long bone fractures in small animals and compared it End threaded Steinmann pinning (ETP) for fixation of long bone fracturesand reported that IILN technique can be used successfully for repair of long bone diaphyseal fractures in dogs in a variety of cases including certain comminuted fractures. Status of fracture fixation and overall clinical outcome was superior in IILN group than ETP group.

Conceicao et al. (2018) combined interlocking nail with locking plate fixation for a distal diaphysis femur comminuted fracture in a dog. Plate-nail osteosynthesis with intramedullary nail of 8 mm inserted, locked with reconstructive plate of 3.5 mm. At 3 weeks, the patient showed functional use of the limb with partial weight bearing. Follow-up radiographs five months postoperatively revealed satisfactory healing of the fracture. However, the orthopedic examination revealed mild lameness of the affected limb. Therefore, the removal of the plate was elected, because it seemed to compromise the integrity of the ligaments and tendons of the stifle. Follow-up examination 3 weeks after the second surgery revealed that the dog had regained full activity without any lameness. A radiograph at 45 days postop (after second surgery) shown that bone was healed. In conclusion, the case reported here documented that the combination of an interlock nail with a locking plate provides a rigid fixation method, promoting satisfactory functional recovery time.

**2.3:Intramedullary interlocking nailing with modified nails and other techniques for fixation of fractures in dogs:**

Dejardin et al. (2006) evaluated torsional loading in simulated canine tibiae for a novel hourglass-shaped interlocking nail with a self-tapping tapered locking design and compared it with standard 8mm ILN. Study was done on 8 canine tibiae. The hourglass shape was designed to preserve the medullary blood supply, and the bullet shape of the distal end was designed to facilitate fracture reduction. Analysis of this study suggested that the novel hourglass shaped ILN system to eliminate torsional instability associated with the use of current ILNs. Thus, the novel ILN may represent a biomechanically more effective fixation method, compared with current ILNs, for the treatment of comminuted diaphyseal fractures.

Asma et al. (2014) carried out the study for the evaluation of the outcomes of dogs' femur fracture unions by using intramedullary pinning and bone plating fixation. Total 8 animals were evaluated in this study. The animals were evaluated at 15, 21, 28 and 35 days for evaluating radiograph aiming to check bone union process. Radiograph studies showed that dogs with intramedullary pinning developed a faster repair process in all observation periods when compared to dogs with bone plating. It was concluded that the intramedullary pinning stimulated the early beginning of bone repair process in dogs when compared to the bone plate fixation.

Chanana (2014) evaluated the clinical efficacy of end-threaded intramedullary pinning for management of various long bone fractures in 25 canines. The positive profile end-threaded intramedullary pin was compared with negative profile end threaded pin. Initially standardization was done in 6 clinical patients presented with long bone fractures. Later end threaded pins were evaluated in 19 clinical cases. In majority of cases, complete weight bearing was observed by 21$^{st}$ to 42$^{nd}$ postoperative day. All the cases were healed with moderate amount of periosteal callus formation. No pin migration and fragments collapse were seen in positive profile pin.

Bruckner et al. (2016) described a clinical study with a newly designed interlocking nail system (Targon (®) Vet) in diaphyseal fractures in cats and small dogs. They conducted study on 57 consecutive cases (49 cats, 8 dogs) with 60 long bone fractures. Median radiographic follow-up was 16 weeks. A total of 12 postoperative complications occurred: 3 minor (slippage of the locking screws) and 9 major. Out of nine, five complications were observed in femoral fractures –irritation of the sciatic nerve, fracture because of a missed fissure, femoral neck fracture. Rest four complications were observed in tibial fractures, 3 with protrusion of the distal locking screw through the skin and 1 with in-growth of the intramedullary nail). It was concluded that implantation of Targon (®) Vet System was feasible in all cases. It provides an alternative system for diaphyseal fracture repair in cats and small dogs.

**Chapter 3**

# Materials and Methods

The study was conducted on the clinical cases of dogs presented for various fractures in the Department of Veterinary Surgery and Radiology, DGCN COVAS Palampur, India from January 2018 to April 2019. The technical programme of work was divided into three parts-

1. Recording regional occurrence of fractures in dogs
2. Clinical application of anatomically contoured intramedullary interlocking nailing technique for stabilization of femoral fractures in dogs
3. Comparative evaluation of different techniques for fixation of femoral fractures in dogs

## 3.1: Recording regional occurrence of fractures in dogs:

For this study, all the clinical cases of dogs presented to department in the period of study were evaluated for fractures. The variables like sex and age of dog, the cause of fracture, the affected bone/s and the type of fractures etc. were recorded and various statistical data like regional incidences and the distribution of fractures were calculated. For categorization of the affected age-groups, the average life expectancy of dog was taken into consideration (table 1) as per Kumar (2016) and Kaur (2017).

**Table 1: Age-group in dogs**

| | |
|---|---|
| Juvenile | <1 years |
| Adult | 1-7 years |
| Senile | >7 years |

The causes of fracture were categorized into automobile accident, fall/jump from height, abusive, dog bite/fight, slipping, struggling, miscellaneous and unknown as per the history narrated by the pet owners.

The numbers of bones affected with fractures were also noted down. Bone-wise, the fractures were classified as femoral, tibial/fibular, metatarsal, humeral, radial/ulnar, metacarpal, phalangeal, pelvic, spinal, mandibular and miscellaneous.

Fractures of all the long bones in dogs were further sub-classified in the following manner –

- On the basis of affected side; whether right or left
- On the basis of the extent of damage to the bone; whether complete or incomplete
- On the basis of the communication of fracture line to the outside environment; whether open or closed

### 3.2: Clinical application of anatomically contoured intramedullary interlocking nailing technique for stabilization of femoral fractures in dogs:

Fifty-three cases of femoral fractures were presented in the period of study. The fractures varied in types, severity and the extent of anatomical involvement and hence out of which, 45 cases were stabilized using different internal fixation techniques like plain Steinmann pinning (SP), Positive profile End threaded screw ended pinning (ETP), Triple K-wiring, Bone Plating (BP), straight intramedullary interlocking nailing (ILN) and Anatomically contoured intramedullary interlocking nailing (ACIILN) as per the suitability of individual case. Description of location and type of fractures and surgical technique used is given below in table no. 2.

All the dogs with femoral fractures were thoroughly examined clinically. They were provided first aid and stabilized with suitable treatment and thereafter subjected to orthopaedic and radiological examinations to determine the kind of orthopaedic interventions.

**Table 2: Different techniques used to repair femoral fractures in dogs**

| | **Proximal extremity (n=5)** | **Proximal diaphysis (n=3)** | **Mid diaphysis (n=23)** | **Distal diaphysis (n=10)** | **Distal extremity (n=12)** |
|---|---|---|---|---|---|
| SP | - | 1 | - | 2 | - |
| ETP | - | - | 12 | 4 | 1 |
| BP | - | - | 1 | 2 | 7 |
| Rush pin | - | - | - | - | 2 |
| IILN | - | 1 | - | - | - |
| ACIILN | - | - | 9 | 1 | - |
| Lag screw | 1 | - | - | - | - |
| Triple K-wiring | 2 | - | - | - | - |
| Unrepaired | 2 | 1 | 1 | 1 | 2 |
| Total | 5 | 3 | 23 | 10 | 12 |

In general, the history and anamnesis of all dogs were recorded in a standard manner and these were subsequently subjected to following examinations before proceeding with any surgical procedure. However, not all examinations were done all cases-

**3.2.1 Anamnesis :** It included the information related to the cause of trauma, time and extent of trauma, status of feed intake and water intake, defecation and urination status, previous treatment, if any; age, breed, sex and the affected bone (left or right).

**3.2.2 Clinical examination:** It included the examination of rectal temperature (°F), respiration rate (breaths/min.), heart rate (beats/min.) and colour of conjunctival mucus membrane, body weight (Kg), status of hydration and neurological status.

**3.2.3 Hemato-biochemical examination**: Examination of Haemoglobin (Hb), Packed cell volume (PCV), Total leukocyte count (TLC) and Total erythrocyte count (TEC), Differential leukocyte count (DLC), Alanine transferase (ALT), Aspartate transferase (AST), Alanine phosphatase (ALP), Bilirubin, Total protein, BUN, Creatinine, Glucose to assess the physical fitness of animal before undertaking any general anaesthesia procedures.

**3.2.4 Orthopaedic examination:** General orthopaedic examinations included examination of pain at the fracture site, crepitation, any sign of inflammation, contusion, mal-angulation as well as status of lameness and weight bearing.

Degree of inflammation and pain at fracture site were described as per Kumar (2016) and Kaur (2017). It was scored from 0-3. The score increased with the severity of inflammation and pain at the fracture site.

**Table 3: Assessment of degree of inflammation and pain at fracture site**

| **Score** | **Degree of inflammation** | **Degree of pain** |
|---|---|---|
| 0 | No inflammation | No pain on moderate digital pressure at fracture site |
| 1 | Low | Pain on moderate digital pressure at fracture site |
| 2 | Moderate | Pain on slight digital pressure at fracture site |
| 3 | High | Pain on just touching the fracture site |

The status of lameness of the affected limb in dogs was assessed by calculating weight-bearing score in standing and walking phases as per Kumar (2016) and Kaur (2017). This was recorded by evaluating them on a weight bearing scale of 0–10. Individual score of standing and walking phases (max. 5 in each) was added to obtain the net weight-bearing score of each patient as described in table 4.

**Table4: Status of lameness and weight-bearing score of dogs**

| **Score** | **During standing phase** | **During walking phase** |
|---|---|---|
| 0 | Test limb not touching the ground | |
| 1 | Toe of test limb touching the ground occasionally | |
| 2 | Toe of test limb touching the ground frequently | |
| 3 | The paw of test limb touching the ground occasionally | |
| 4 | The paw of test limb touching the ground frequently | |
| 5 | The paw of test limb touching the ground regularly | |
| Net weight-bearing score | **Score in standing+ Score in walking** | |

**3.2.5 Radiographic examination:** Standard medio-lateral and cranio-caudal views of the affected as well as contralateral limb were taken to assess the type of fracture and selecting the dimensions of implant's to be used for fracture fixation.

**3.2.6 Goniometric examination:** Goniometer was used to measure the angle of stifle and hock joints. Both the extension and flexion angles were measured before the surgery to assess the range of motions as described by Newton and Nunamaker 1985. Goniometry of both normal (contra-lateral) and affected limbs were done for comparison.

**3.2.7 Fracture assessment score:** Various mechanical, biological and clinical factors fracture assessment scores of the patients were calculated. The description of these factors and scoring are given below in table no. 5

**Table 5: Fracture assessment scoring (FAS) for dogs**

| | Factors | | Score | | | |
|---|---|---|---|---|---|---|
| | | | 1-3 | 4-7 | 8-10 | |
| 1. | Mechanical factors | Size of dog | Large | Medium | Small | Total score/2 |
| 2. | | No of limbs injured | Multiple | Pathological condition | Single | |
| 3. | Biological factors | Age | Senile | Adult | Juvenile | Total score/6 |
| 4. | | Health status | Poor | Fair | Good | |
| 5. | | Bone type | Cortical | Both | Cancellous | |
| 6 | | Approach | Extensive | Open | Closed | |
| 7. | | Injury velocity | High | Medium | Low | |
| 8. | | Tissue envelope | Poor | Fair | Good | |
| 9. | Clinical factors | Client compliance | Poor | Fair | Good | Total score/2 |
| 10. | | Patient compliance | Poor | Fair | Good | |
| | | | | | | Net score (max. 30) |

Anatomically contoured intramedullary interlocking nailing technique was eventually selected to fix 10 femoral fractures of dogs. In these, 9 fractures were mid femoral and 1 was just slightly distal diaphyseal.

**Selection of patient:** Selection of patient for application of ACIILN technique depended upon the location of fracture, type of fracture, diameter of medullary cavity and length of fractured fragments and bone. Dogs where fractures primarily involved mid (or just slightly distal) diaphysis were chosen for fixation with ACIILN. This was done to ensure sufficient number of locking screws to be placed on either side of fracture. Moreover, fissured and highly comminuted fractures were not attempted to fix with ACIILN. Lengths of fractured fragments were also taken into considerations because at least 2 cortical screws should be there to achieve adequate fixation. Length of bone and diameter of medullary cavity was also taken into consideration before implant fixation; because of availability of implant of fixed dimensions in department.

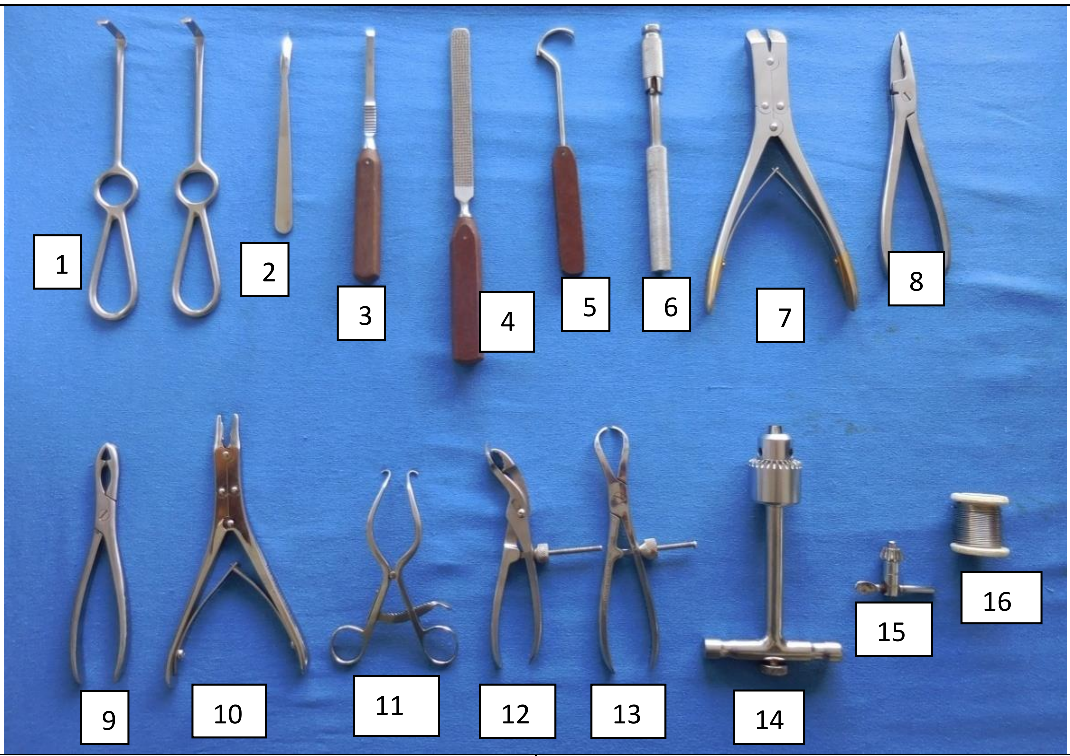
**Selection of ACIILN implant:** Pre-operatively, implant selection was done on the basis of radiograph. The length of nail was determined on the basis of medio-lateral radiograph, whereas diameter of nail and length of screws were predetermined on the basis of cranio-caudal radiograph. Narrowest diameter of medullary cavity at the level of isthmus was considered as the most probable diameter of nail to be used.

These solid stainless steel rod like ACIILN were developed by the department specifically for fixation of femoral fractures in dogs. Nails were gently bent at an angle of 8° for better alignment in curved diaphysis of canine femur with convex surface facing cranially. Different trials were done on different dogs' femur and it was found that bone of dog is caudally bent by 6 to 11°. So nail with a mean angle of 8° was devised to repair femoral fractures in dogs.

The ACIILN were developed in various diameters like 5.0, 6.0 and 7.0 mm. The 5.0mm nail was meant to be used with 2.0mm cortical screws whereas 6.0and 7.0mm nails with 2.7mm cortical screws. The base of ACIILN was developed in such a manner that a single conical bolt can fit in to all of them so that additional bolts are not required during surgical fixations using different sized nails. The length of ACIILNs ranged from 11 to 17 cm with 1 mm difference in ACIILN of every diameters i.e. 5-7 mm.

Additionally, the distal end of ACIILN was provided with a shallow recess to engage the tip of a guide pin to facilitate its seating in to the bone.

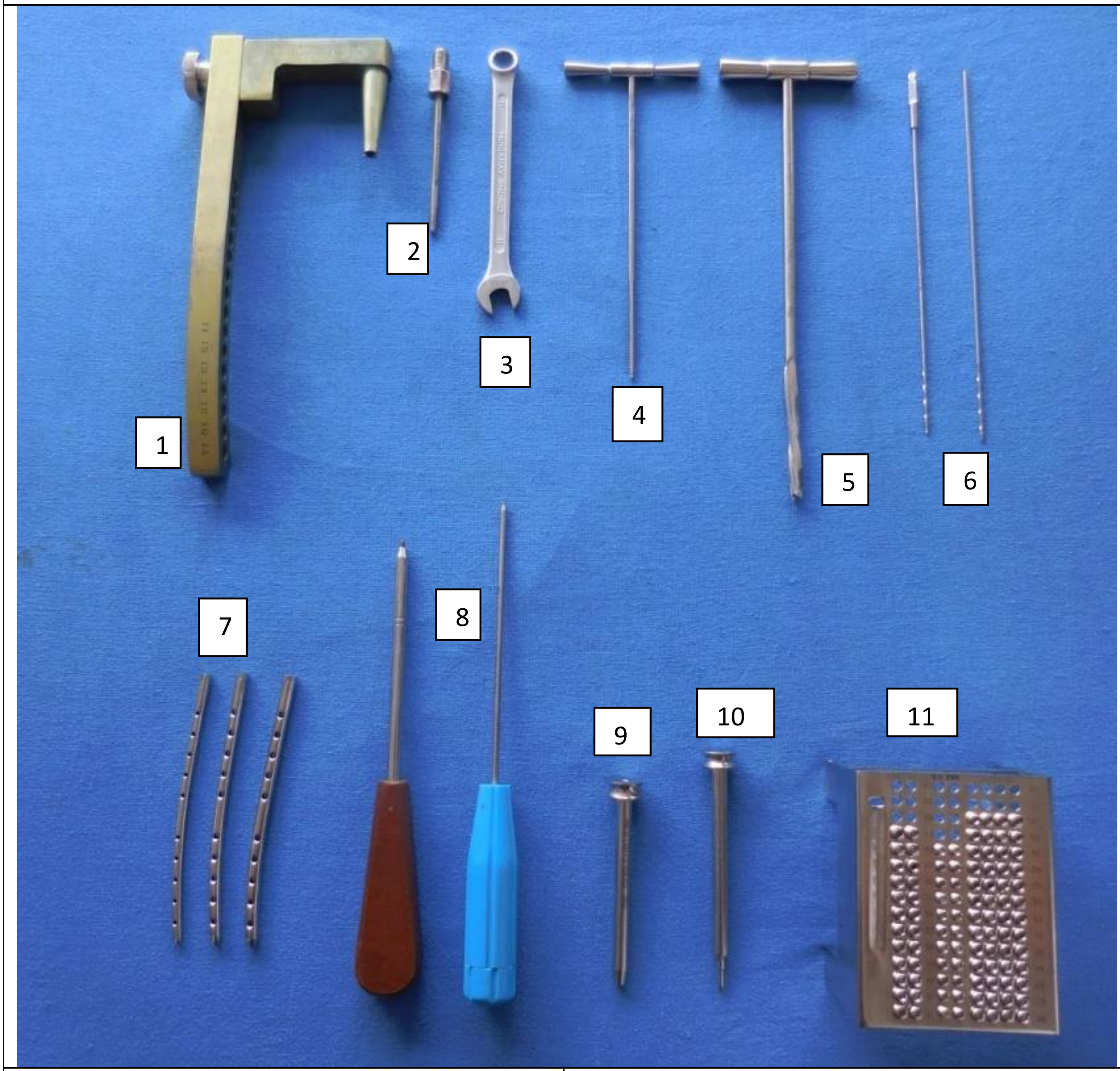
**Fig 1: General orthopaedic instruments**




| | |
|---|---|
| **1.** Langenbeck retractor | **9.** Ferguson bone holding forceps |
| **2.** Hohmann retractor | **10.** Bone rongeur |
| **3.** Periosteal elevator | **11.** Gelpi retractor |
| **4.** Bone rasp | **12.** Self –retaining bone holding forceps |
| **5.** Wire passer | **13.** Pointed bone reduction forceps |
| **6.** Wire twister | **14.** Jacob's chuck |
| **7.** Orthopaedic wire cutter | **15.** Jacob's chuck key |
| **8.** Orthopaedic plier | **16.** Orthopaedic wire |

Besides, general orthopaedic instruments, a number of specialized ancillary items were required for proper application of ACIILN. Main among them was an aiming device (Jig); it was specially designed to exactly align with the cannulations of different ACIILN. The jig was designed in such a way that the same instrument could be used to seat ACIILN in either left or right femur of dog. For it, instead of having fixed arms, the jig was developed with detachable arms whose sides could be flipped after removing the attached bolts and a right sided jig could turn in to left side one and vice-versa.

**Fig 2: Instruments for anatomically contoured intramedullary interlocking nailing for fixation of femoral fractures in dogs**




| | |
|---|---|
| **1.** Jig/Aiming device<br>**2.** Nail attachment conical bolt<br>**3.** Spanner<br>**4.** Bone tap<br>**5.** Reamer<br>**6.** Drill bits | **7.** Anatomically contoured femoral interlockingnails<br>**8.** Hexagonal tip screw drivers for 2.0, 2.7 and 3.5 mm cortical screws<br>**9.** Drill bit sleeve<br>**10.**Trocar<br>**11.** Screw box |

**Surgical procedure for fixation of femoral fractures in dogs with ACIILN:**

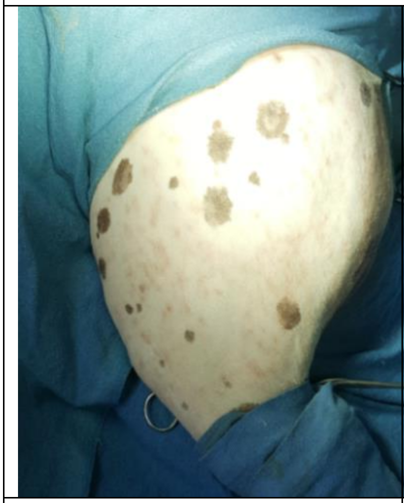
The surgical procedure to fix femoral fractures with ACIILN was done under the general anaesthesia. The dogs were anaesthetized using standard protocol usually involving Inj. Atropine @ 0.04 mg/kg SC, Butorphanol 0.2 mg/kg IM, Diazepam @ 0.5 mg/kg IV, and Propofol @ 3-5 mg/kg IV whereas, volatile anaesthetic 'Isoflurane' was used for maintenance of anaesthesia. Standard cranio-lateral site was approached as described by Newton and Nunamaker (1985). Surgical technique was similar to as standardized by Kumar (2016) except use of ACIILN instead of straight ILNs. Moreover, instead of Steinmann pins, standard specialized straight reamers were used to do intramedullary reaming to place ACIILN later. Post-operative management included administration of routine antibiotics, non-steroidal anti-inflammatory drugs, diet-supplements, anti-septic dressing and bandaging as and when required. Owners were advised to ensure cage rest for 15 days and leash-walking thereafter until fracture healing. .

The dogs were evaluated on the basis of various intra and postoperative examinations at different time intervals. Following observations were recorded and analyzed-

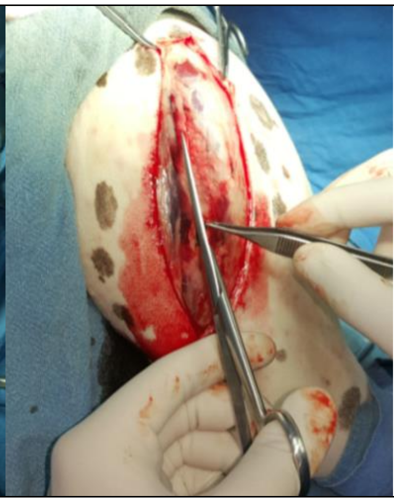
**Intra-operative observations:**

The degree of technical difficulty, extent of manipulation of tissues, status of fracture reduction and fixation were recorded subjectively and given different scores as per table 6. Duration of surgery in minutes from the start of incision and before the closure of surgical wound was also recorded. Besides, the status of fracture and associated soft tissue damage at the site was also recorded and correlated with post-operative observations.

**Fig 3: Application technique of ACIILN for femoral fractures in dogs**



Extent of area prepared for surgery

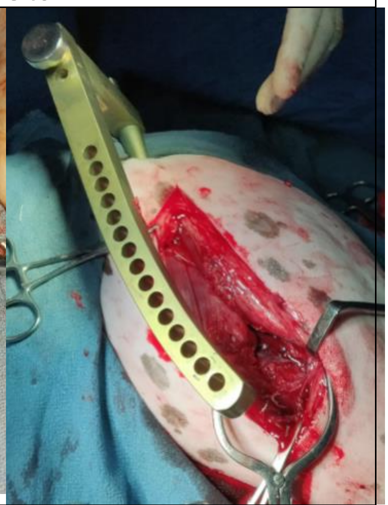


Incision on tensor fascia lata

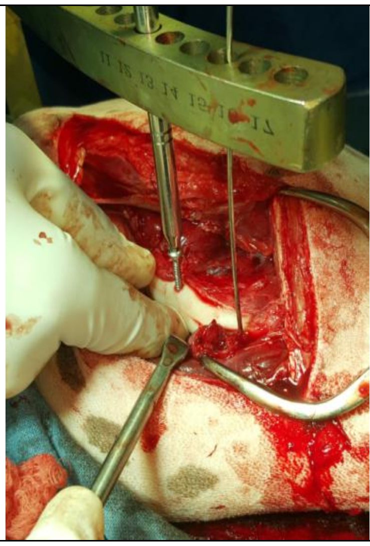
Separation of vastus lateralis and biceps femoris to expose fracture site

Intramedullary reaming of bone

Seating of ACIILNusing guide pin



Placement of nail with attached aiming device



| Drilling for screw insertion | Placement of cortical screws | Closure of surgical wound |
|---|---|---|

**Table 6: Scoring for intra-operative observations**

| **Observations** / **Score** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Extent of manipulation and soft tissue damage | Low | Moderate | High | Very high |
| Degree of technical difficulty | | | | |
| Status of fracture reduction | Poor | Fair | Good | Excellent |
| Status of fracture fixation | | | | |

**Post-operative observations:**

The dogs were periodically examined post-operatively to assess the clinical progress.Routine clinical, haemato-biochemical, orthopedic, goniometric and radiological examinations as described in pre-operative observations part above, were done at the time of every reappraisal of the patient as per the need. Additionally, the surgical site was examined for its gross appearance and healing status. The muscle atrophy in the affected limb, if any, was also recorded and graded as follows:

**Table 7: Scoring for evaluating the postoperative status of muscle atrophy in the affected limb**

| | |
|---|---|
| 0 | No atrophy |
| 1 | Low |
| 2 | Moderate |
| 3 | High |

### 3.3: Comparative evaluation of different techniques for fixation of femoral fractures in dogs:

During the period of study, 45 femoral fractures out of total 53 were fixed with different surgical techniques. Among them, ETP technique was most commonly utilized (n=17) followed by ACIILN (n=10) and bone plating (10). However, as comparative evaluation can only be done in similar types of fractures, only mid diaphyseal fractures with comparable FAS were included for this phase and the fracture involving most distal and proximal aspects of the femur were excluded from the study.

Thus, the study mainly dealt with comparative evaluation of ACIILN with that of ETP technique utilized for fixation of mid-diaphyseal fractures. The ETP or End-threaded Positive Profile Self-tapping Screw-ended Pins (ADMIT pins, KK Surgicals, India) were modified Steinmann pins having cancellous threads towards its distal screw-end and trocar-shape towards proximal end. The surgical technique for ETP technique was followed as described by Chanana (2014).

#### 3.3.1: Coding for describing the implant/s in this study

For easy understanding of the details of implants with regards to their dimensions, the number of screws used and auxiliary fixation, if any, a numerical coding was used as described by Kumar (2016). The details are as follows-

**ACIILN:** The first digit of the coding represents the diameter of ACIILN (mm); the second digit, the length (cm); the third digit, the number of proximal screws; the fourth digit, the number of distal screws; the fifth digit, the number of cerclage wires used, if any, and the digit in parenthesis representing the diameter of orthopaedic wire (G). For example, the code ‘5-10-2-2-1(22)’ means stabilization of fracture by a 5 mm wide, 10 cm long ACIILN fixed with 2 proximal and 2 distal screws along with 1 cerclage wire of 22 G.

**ETP:** The first digit represents the thread diameter (mm) of ETP used; the second, the diameter of the core/shaft (mm); the third, the number of cerclage wires used, if any and the last digit in parenthesis, the diameter (gauge) of the cerclage wires used. For example, the ETP code '5.5-4-1(22)' means stabilization of fracture by using an ETP having a 5.5 mm threads over a 4 mm core and 1 cerclage wire of 22 G.

All these peri-operative details of the patient were recorded systematically in a specially-designed 'Orthopaedic examination Sheet' for proper analysis of data. The sample is given below-

**Orthopaedic examination Sheet**

| | | | |
|---|---|---|---|
| Case no. | | Date | |
| Owner's name & address | | Phone No. | |
| Species | Breed | Age | Sex |

| **History:** |
|---|
| |

| **Clinical observations** | | | | | | |
|---|---|---|---|---|---|---|
| Date | Rectal temp($^{o}$F) | Respiration rate | Heart rate | CMM | Body Wt.(Kg) | Any other |
| | | | | | | |
| | | | | | | |

| **Preoperative observations** |
|---|
| |

| **Date** | **Radiological observations** |
|---|---|
| Preoperative | |
| Postoperative | |

| **Goniometric observations** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Affected limb | | | | Contralateral limb | | | |
| Date | Stifle extended | Stifle flexed | Hock extended | Hock flexed | Stifle extended | Stifle flexed | Hock extended | Hock flexed |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

**Fracture assessment scoring (FAS) system**

| | Factors | | Score | | | Average score |
|---|---|---|---|---|---|---|
| | | | 1-3 | 4-7 | 8-10 | 1-10 |
| 1. | Mechanical factors | Size of dog | Large | Medium | Small | Total score/2 |
| 2. | | No. of limbs injured | Multiple | Pathological condition/ soft tissue damage | Single | |
| 3. | Biological factors | Age | Senile | Adult | Juvenile | Total score/6 |
| 4. | | Health status | Poor | Fair | Good | |
| 5. | | Bone type | Cortical | Both | Cancellous | |
| 6 | | Approach | Extensive | Open | Closed | |
| 7. | | Injury velocity | High | Medium | Low | |
| 8. | | Tissue envelope | Poor | Fair | Good | |
| 9. | Clinical factors | Client compliance | Poor | Fair | Good | Total score/2 |
| 10. | | Patient compliance | Poor | Fair | Good | |
| | | | | | Net score (max. 30) | |

| Intraoperative observations | | | | |
|---|---|---|---|---|
| **Extent of manipulation of soft tissue** | Low | Moderate | High | Very high |
| **Degree of technical difficulty** | Low | Moderate | High | Very high |
| **Status of fracture reduction** | Poor | Fair | Good | Excellent |
| **Status of fracture fixation** | Poor | Fair | Good | Excellent |

| **Fixation technique used** | | Dimensions |
|---|---|---|

| Date | **Complications if any** |
|---|---|
| Intraoperative | |
| Postoperative | |

| Post-operative | |
|---|---|
| Angular deformity, if any | |
| Implant removed on and difficulties involved in implant removal, if any | |

| Status of weight bearing | | | |
|---|---|---|---|
| Date | 0-Test limb not touching the ground<br>1-Toe of test limb touching the ground occasionally<br>2-Toe of test limb touching the ground frequently<br>3-The paw of test limb touching the ground occasionally<br>4-The paw of test limb touching the ground frequently<br>5-The paw of test limb touching the ground regularly | 0-Test limb not touching the ground<br>1-Toe of test limb touching the ground occasionally<br>2-Toe of test limb touching the ground frequently<br>3-The paw of test limb touching the ground occasionally<br>4-The paw of test limb touching the ground frequently<br>5-The paw of test limb touching the ground regularly | Net score |
| Preop. | | | |
| Postop. | | | |

| **Date** | **Degree of inflammation**<br>10-no inflammation<br>1-low<br>2-moderate<br>3-high | **Status of pain**<br>0: no pain<br>1: pain on moderate digital pressure<br>2-pain on slight digital pressure<br>3-pain on just touching | **Healing of surgical site**<br>0-unsatisfactory<br>1-satisfactory | **Muscle atrophy**<br>0-nil<br>1-low<br>2-moderate<br>3-high | **Change in gait, if any:** |
|---|---|---|---|---|---|
| Preop. | | | | | |
| Postop. | | | | | |

**Chapter 4**

# Results and Discussions

The results have been discussed under following three heads-

4.1: Regional occurrence of fractures in dogs

4.2: Clinical application of anatomically contoured intramedullary interlocking nailing technique for stabilization of femoral fractures in dogs

4.3: Comparative evaluation of different techniques for fixation of femoral fractures in dogs

## 4.1: Regional occurrence of fractures in dogs

In this period of study, spanning from 1$^{st}$January 2018 to 30$^{th}$ April 2019,4619 clinical cases were registered in the teaching veterinary clinical complex (TVCC) comprising 2589 dogs, 1429 cattle, 112 equine and 489 others animal species. Out of these 4619 animals, 1839 (39.81%) were presented to the Department of Veterinary Surgery and Radiology, DGCN College of Veterinary and Animal Sciences, CSKHP Agricultural University, Palampur, India.

Out of 1839 cases presented to the department, 1337 (72.70%) were dogs comprising of 859 males and 478 females. Out of these 859 males; 528 were juvenile, 221 adults and 110 senile; and out of 478 females 228 were juvenile, 172 adults and 78 senile.

Among these 1839 clinical cases, 262 were of fractures in different animal species; significant majority of them were in dogs (204). Thus, the percent distribution of fractures in dogs was calculated to be 77.86 and the incidence as 15.26 (Table 8)-

**Table 8: Distribution and incidence of fractures in dogs**

| Total no of cases | Cases with fractures | Distribution (%) | Incidence (%) |
|---|---|---|---|
| 1337 | 204 | 77.86 | 15.26 |

Other similar studies done recently in the same geographical area also reported significant number of dogs being affected with fractures. Kumar (2016) reported 64.11 per cent distribution rate of fractures in dogs while incidence was found to be 13 per cent. Whereas, Kaur (2017) reported distribution of fractures in dogs as 72.56 per cent and incidence to be 14.61 percent. Comparison of these studies indicates a steady increase over the years in not only overall percentage of fracture cases in dogs among animals presented to the department but also the overall increase in the incidence rate of fracture too.

Studies done in other geographical area also revealed greater percentage of fractures in dogs among all animal species presented for treatment to a veterinary institution. For example, Singh et al. (2017) reported that among 153 cases of fractures, 90 (58.82%) cases of fractures were in dogs.

### 4.1.1. Sex-wise distribution and incidence of fractures in dogs

More number of males (74.50%) were presented with fracture than females (25.49%) and incidence of fracture was also higher in males (17.69% compared to 10.7% in females).

**Table 9: Sex-wise distribution and incidence of fractures in dogs**

| Sex | No. of fracture cases | Distribution% | Incidence% |
|---|---|---|---|
| Male | 152 | 74.50 | 17.69 |
| Female | 52 | 25.49 | 10.7 |
| Total | 204 | 100 | 15.26 |

These findings are different from Kumar (2016) who reported higher incidence in females (13.48%) than males (12.78%) in the same geographical area not very long ago. But the findings of the present study are similar to those of Simon et al. (2010) and Minar et al. (2013) who reported greater percentage of males affected with fractures (61.5 and 54% respectively). The males being more aggressive and wandering in nature are likely to get affected more with traumatic injuries including fractures. However, different findings about sex-wise occurrence of fractures during different time period in the same geographical area indicates towards no specific correlation of gender with fractures in dogs. Kaur (2017) also reported almost comparable rate of incidence among male (14.6%) and female dogs (14.5%) in the same geographical area.

### 4.1.2. Age-wise distribution and incidence of fractures in dogs

In dogs, majority of fractures were observed in juvenile age-group with distribution rate of 51.47 per cent, followed by adult (39.21%) and senile (9.31%). However, the incidence of fractures were more in adult (20.3%) followed by juvenile (13.89%) and senile (6.5%) age-groups.

In another study done in the same geographical area, Kumar (2016) also reported a higher distribution rate of fractures (67.88%) in juvenile dogs followed by adults (31.19%) and senile (0.91%). Kaur (2017) also found that majority of fractures cases affect juvenile group of dogs (62.18%) followed by adult (28.53%) and senile (9.24%).

The findings of these different studies in this geographical area are in accordance with findings of studies done elsewhere such as Kushwaha et al. (2011) reported 72.97% distribution of fracture cases in juvenile dogs; however the incidence rate of fracture wasn’t reported in that study.

Higher distribution of fracture in young dogs in present study may be attributed to their higher population in the area because otherwise the incidences of fractures were consistently more in adult age-groups over the years.

Senile dogs are traditionally considered more prone to fractures due to more brittle nature of bone but the significantly lesser incidence of fractures in their age-group compared to adults indicate invalidity of this perception. Moreover, less active and guarded kind of life-style of senile dogs may be responsible for lesser incidence of fractures in them.

**Table 10: Age-wise distribution and incidence of fractures in dogs**

| Age group | No. of fracture cases | Distribution% | Incidence% |
|---|---|---|---|
| Juvenile (<I year) | 105 | 51.47 | 13.89 |
| Adult (1-7 year) | 80 | 39.21 | 20.3 |
| Senile ( >7 years) | 19 | 9.31 | 6.5 |
| Total | 204 | | |

### 4.1.2. Bone-wise distribution of fractures in dogs

Femur was found to be most affected bones (24.76%), followed by tibia (16.35%), radius and ulna (15.88%), humerus (10.74%), pelvis (9.81%), vertebrae (8.41%), metacarpals (3.74%), metatarsals (2.80%), mandible (2.80%), phalanges and tarsals (1.87% each), skull (0.93%) and carpals (0.46%).

Among the 204 cases of fractures in dogs, 10 animals had fractures of more than one bone and thus the total number of fractured bones in 204 dogs were 214. For the simplicity, fractures in pelvis at more than one location was counted as one entity in this study.

**Table 11: Bone-wise distribution of fractures in dogs**

| Type of bone involved | Total | Distribution% |
|---|---|---|
| Femur | 53 | 24.76 |
| Tibia | 35 | 6.35 |
| Humerus | 23 | 10.74 |
| Radius and ulna | 34 | 15.88 |
| Metacarpals | 8 | 3.74 |
| Phalanges | 4 | 1.87 |
| Metatarsals | 6 | 2.80 |
| Tarsals | 4 | 1.87 |
| Carpals | 1 | 0.46 |
| Pelvis | 21 | 9.81 |
| Vertebrae | 18 | 8.41 |
| Skull | 2 | 0.93 |
| Mandible | 5 | 2.34 |
| Total | 214 | |

These findings are once again in conformity with those of Kumar (2016) and Kaur (2017) where femur was found to be the most affected bone with fractures (33.02% and 23.52% respectively). Sran et al. (2016) working in different geographical area also reported that among long bones, the most commonly fractured bone was femur (44.48%) in dogs.

It is important to note that not only the femur but overall the different bones of hind limb put together form a significant majority over forelimb fractures in dogs consistently over the years in studies after studies (Harasen, 2003, Kumar, 2016, Kaur 2017). And automobile accidents also being the most common cause of fractures in these studies, it can be premised that while animals tend to flee after seeing an impending trauma, they inadvertently expose their hindquarters to the major force of impact.

### 4.1.3. Etiology-wise distribution of fractures in dogs

The major causes of fractures in dogs were determined to be automobile accident (47.06%), fall from height (26.96%), dog bite/animal fight (3.92%), slipping (3.43%), struggle (2.94%) and abusive (0.98%) whereas in 3.92 per cent cases, reasons were disparate and grouped under miscellaneous and in10.78 per cent cases the cause remained unknown.

**Table 12: Etiology-wise distribution of fractures in dogs**

| Etiology | No. of cases | Distribution% |
|---|---|---|
| Automobile accident | 96 | 47.06 |
| Fall from height | 55 | 26.96 |
| Dog bite/ Animal fight | 8 | 3.92 |
| Struggle | 6 | 2.94 |
| Slipping | 7 | 3.43 |
| Abusive | 2 | 0.98 |
| Miscellaneous | 8 | 3.92 |
| Unknown | 22 | 10.78 |
| Total | 204 | 100 |

The major known cause of fractures as automobile accidents in dogs was also reported by Kumar (2016) and Kaur (2017). Automobile accidents generally presents high impact trauma resulting into fracture of bones. These findings are also in accordance of with other workers like Ben Ali (2013) and Sran et al. (2016) who reported that automobile accidents as the most common cause of fractures (44.48%) in dogs.

### 4.1.4. Classification of long bone fractures on the basis of communication of fracture with environment and extent of damage to the bone

Tibia is the most common among all long bone to be suffering from open fractures (20%) whereas, no case of open fracture was reported in femur. This might be due to the fact that femur is surrounded and protected by heavy musculature while there is little muscle mass on the tibia.

Percentage of complete fractures among long bones were 92.40 per cent in femur; 91.43 per cent in tibia; 91.30 per cent in humerus and 100 per cent in radius and ulna.

Kumar (2016) reported the percentage of complete fractures in femur as high as 94.44 per cent whereas it was 84.46 per cent in tibia, 81.18 per cent in humerus and 100 per cent like present study in radius/ulna.

**Table 13: Classification of long bone fractures on the basis of communication with environment and the extent of damage to bone**

| Bone | Closed (Distribution %) | Open (Distribution %) | Complete (Distribution %) | Incomplete (Distribution %) | Total |
|---|---|---|---|---|---|
| Femur | 53 (100%) | - | 49 (92.40%) | 4 (7.55%) | 53 |
| Tibia | 28 (80%) | 7 (20%) | 32 (91.43%) | 3 (8.57%) | 35 |
| Humerus | 21 (91.30%) | 2 (8.69%) | 21 (91.30%) | 2 (8.69%) | 23 |
| Radius and ulna | 32 (94.18%) | 2 (5.88%) | 34 (100%) | - | 34 |

### 4.1.4. Classification of long bone fractures on the basis of affected side

In femur and humerus, the right side was more affected (52.83% and 56.28% respectively), while in tibia and radius/ulna, the left side was more affected (62.86% and 50% respectively). Bilateral fractures were recorded in 3.77and 5.88 per cent cases in femur and radius/ulna respectively.

The comparison of the findings with other similar studies (Kushwaha et al. 2011, Kumar 2016, Kaur 2017) revealed no particular predisposition of any particular side of the long bones for fractures in dogs and thus any variation or similarity among studies may be purely by chance.

**Table 14: Classification of long bone fractures on the basis of affected side of the bone**

| | Left side | Distribution% | Right side | Distribution | Bilateral | Distribution% | Total |
|---|---|---|---|---|---|---|---|
| Femur | 23 | 43.40 | 28 | 52.83 | 2 | 3.77 | 53 |
| Tibia | 22 | 62.86 | 13 | 37.14 | - | - | 35 |
| Humerus | 10 | 43.48 | 13 | 56.52 | - | - | 23 |
| Radius and ulna | 17 | 50 | 15 | 44.11 | 2 | 5.88 | 34 |

### 4.2: Clinical application of anatomically contoured intramedullary interlocking nailing technique for stabilization of femoral fractures in dogs

Fifty-three cases of femoral fractures were presented to the department of surgery in the period of study. Based on the suitability of clinical cases, the ACIILN was used in 10 cases of simple mid (n=9) to slightly distal (n=1) diaphyseal fractures. Fissured and highly comminuted fractures were not attempted with this technique and so were more distal and proximal ones. This was done with the purpose to accommodate at least 2 screws in both major segment of fractures easily.

Details of cases regarding age, sex, breed, cause of fracture, side of femur affected, and any other bone involved if any and time period from trauma to internal fixation (TIF) days, are given in the table no. 15.

Range of age of the dogs in this group was from 4-15 months and weight from 10-30 Kgs. Out of 10 cases, 6 were males and 4 females. Fracture was closed type in all dogs. Automobile accident was the cause of fracture in majority of cases (8 out of 10). The overall time lag from trauma to internal fixation of fracture (TIF) ranged from 1-6 days. The time lag was due to multiple factors like delayed presentation of case, different pre-operative periods for stabilizing the individual patient for surgery and pre-occupation of the surgeons.

**Table 15: Details of dogs treated with ACIILN**

| Case no | Age (Months) | Sex | BW (kgs) | Cause of fracture | Femur side | Any other bone involved (if any) | TIF (days) | Breed |
|---|---|---|---|---|---|---|---|---|
| 1 | 8 | F | 12.5 | Automobile accident | Left | _ | Unknown | Non-descript |
| 2 | 12 | M | 16 | Fall from height | Right | _ | 1 | Pomeranian |
| 3 | 11 | M | 25 | Automobile accident | Right | Open Metatarsals fracture of same limb | 2 | Doberman pinscher |
| 4 | 5 | F | 17 | Automobile accident | Left | - | 6 | Pit-bull |
| 5 | 5 | F | 20 | Automobile accident | Left | - | 2 | Mixed |
| 6 | 5 | M | 20 | Automobile accident | Left | - | 3 | Pit-bull |
| 7 | 15 | M | 30 | Automobile accident | Right | Open tibio-tarsal fracture of contralateral limb along with pelvis fracture | 2 | Dalmatian |
| 8 | 5 | F | 15 | Automobile accident | Right | - | 4 | Non-descript |
| 9 | 4 | M | 14 | Automobile accident | Left | Closed distal diaphyseal transverse fracture of tibia same limb and pelvis fracture | 5 | Non-descript |
| 10 | 3 | M | 10 | Fall from height | Right | - | 4 | Non-descript |

### 4.2.1: Fracture assessment scores, implant selection and placement of ACIILN

Fracture assessment score (FAS), obtained by adding the mean scores of mechanical, biological and clinical factors ranged from 13.5-23. The utilized ACIILN diameter varied from 5 to 7mm and length from 11 to 16 cm. The 6mm diameter nail was the most commonly used implant for the purpose. No linear correlation was found between body weight and implant size. However, this finding is slight different with of finding of Kaur (2017) where larger size nails were used in heavier dogs and vice-versa. In fact, the ACIILNs with diameter lesser than that could be accommodated within the medullary cavity of fractured femurs were deliberately chosen to minimize the extent of intramedullary reaming that is required to seat the nail within the bone so as to preserve medullary blood supply as much as possible. A bigger nail was used in a case or two only when suitable length of less thick nail wasn't available at the time of surgery.

**Table 16: Fracture assessment score and implant selection**

| Case no. | FAS (30)- M/B/C | Implant |
|---|---|---|
| 1 | 20.5 (6.5/5/9) | 7-15-3-2 |
| 2 | 17 (8/5/4) | 5-14-2-3 |
| 3 | 13.5 (2.5/4/7) | 7-16-3-3 |
| 4 | 20 (6.5/6/7.5) | 6-15-2-2 |
| 5 | 18.1 (8.5/4.6/5) | 6-11-3-3 |
| 6 | 20.8 (7/6/9) | 6-15-3-2 |
| 7 | 12.3 (1.5/3.3/7.5) | 6-14-2-3 |
| 8 | 18 (8/6/4) | 6-13-3-2 |
| 9 | 18.8 (5/4.8/9) | 6-13-2-2 |
| 10 | 23 (6.5/5/9) | 7-12-2-3 |

### 4.2.2:Pre-operative observations:

Various pre-operative observations like pain, inflammation, muscle atrophy and weight-bearing were comparatively evaluated with post-operative findings. These have been discussed along with post-operative observations for ease of analysis.

### 4.2.3: Intra-operative observations:

The surgical technique for anatomically contoured intramedullary interlocking nailing (ACIILN) was more or less similar to that of routine conventional straight IILN technique. Adequate exposure of femoral shaft could be achieved following standard cranio-lateral incision. The smaller fragments of fractured bone were removed and a gentle debridement of tissue was done and the exposed surgical site was flushed gently with sterile balanced salt solution (BSS). The fracture site was examined thoroughly for any major damage to vessels or nerves. The diameter and length of the ACIILN to be used was finalized by actually placing a portion of nail inside the medullary cavity for the time being. Thereafter, reaming of medullary cavity was done using straight hand-held reamers starting with one having 4 mm diameter and employing another reamer with a greater diameter progressively increasing by 1 mm each time. The intramedullary reaming was continued in both fracture segments until a space was created that was at least 1 mm more than the diameter of ACIILN to be used. The nail insertion site from sub-trochanteric fossa was also opened during this process gently. The reamer was then removed and a Steinmann pin was introduced in the proximal segment in a retrograde manner and its trocar-ended tip was pushed out of ACIILN insertion site at sub-trochanteric fossa taking care to keep its direction slightly anteriorly so as not to damage sciatic nerve inadvertently. The skin wound at this site was enlarged enough to accommodate the diameter of ACIILN to be inserted afterwards. Then, the selected ACIILN was mounted over aiming device (Jig) and the recess over its tip was engaged with the tip of Steinmann pin (exiting from sub-trochanteric fossa) meant to act as guide-pin. While the Steinmann pin was withdrawn, the ACIILN was simultaneously advanced in to the medullary cavity. Once, the ACIILN reached inside the medullary cavity of the proximal segment of bone, the Steinmann pin was removed from the site and the fracture was reduced and the ACIILN pushed in to distal segment of fracture as deep as possible. If, the ACIILN could be easily pushed into the medullary canal, it was finally seated at site otherwise, it was retracted back and additional incremental intramedullary reaming was accomplished before further attempting to seat it at the site. It was observed that additional reaming to the extent of 2-3 mm was often required in distal segment of fracture to accommodate the nail whereas, in proximal fragment, a 1 mm larger reaming than the diameter of nail was sufficient.

As the reamers were straight, but the distal end of the femur as well as that of ACIILN was curved, hence to prevent iatrogenic angular re-curvaturm deformity of distal femur, wider reaming of distal metaphyseal area had to be done by angling the reamer many times in cranial to caudal directions during this process. But it proved difficult in many cases where the distal segment was longer and angling the reamer beyond a limit wasn’t possible. In such instances (case nos. 7 and 9), the ACIILN could not be placed as distally as originally contemplated. In another instance (case 10), an undesirable straighter course of intramedullary reaming in distal segment of fracture lead to inadvertent piercing of distal cranial cortex just above trochlea and consequently wrong placement of nail-end there.

After temporary seating of ACIILN in the medullary cavity of bone after reduction of fracture, drill sleeve was mounted over bone through cannulation of jig where hole was to be drilled. A suitable sized drill bit (1.5 mm for seating 2.7 mm screws) was thereafter utilized to drill hole in to the proximal segment of bone covering both cortices through corresponding holes of *in-situ* ACIILN. The threads were tapped in this hole using hand-held tap under a tap sleeve and the suitable length screw was fastened. This process was repeated in distal fragment and then over other holes until fracture stability was deemed sufficient. Minimum of 2 proximal and 2 distal screws were applied in each major fracture segment to achieve adequate fixation. More number of screws were applied wherever it became possible easily. Therefore, the number of screws at proximal and distal segments varied according to the individuality of case. In none of the cases, the distal or proximal segment of the fractured bone was left without screw and thus it is inferred that all ACIILNs were applied in static mode.

Frequent problems were faced during drilling of distal holes to align with cannulation of ACIILN. Frequent misalignment of distal screws occurred, particularly at the most distal level. It was due to the sloping anatomy of distal femur leading to slipping of drill bits a little despite use of appropriate drill sleeves and prior use of trocar to indent the surface. It resulted in causing an eccentric hole and hence screws often missed the ACIILN cannulation. Many times, this misalignment could be appreciated at the time of surgery itself particularly when no other screw was engaging the distal fragment, but many a times such faults came to notice only when postoperative radiographs were examined. However, subsequent radiographs revealed that at least one screw could still be fixed properly in either segment of fractures in all cases.

Another technical difficulty faced was to determine the exact length of screws to be used. The available depth gauge was bigger than what the screw hole could accommodate and hence, screws had to be placed utilizing another depth gauge which is commonly used during bone-plating. This resulted in overestimating the screw hole length quite often and thus many screws protruded far in to the soft tissue.

The duration of surgery for application of ACIILN ranged from 35-75 minutes (63±3.51s). The score of technical difficulty ranged from 1-3 with a mean score of and 1.7 ± 0.21 respectively. The technical difficulties also led to increased manipulation of soft tissue whose mean score was calculated to be 1.9±0.31. Status of fracture reduction and fixation however, was quite good with a mean score of 3.8 ± 0.13 and 3.3 ±0.21 respectively.

**Table 17:Intra-operative observations in cases of femoral fractures repaired with ACIILN**

| S.N. (ACIILN) | Duration of surgery (In min.) | Extent of manipulation and soft tissue damage | Degree of technical difficulty | Status of fracture reduction | Status of fracture fixation |
|---|---|---|---|---|---|
| 1 | 65 | 2 | 2 | 4 | 3 |
| 2 | 75 | 2 | 2 | 4 | 4 |
| 3 | 70 | 1 | 1 | 4 | 4 |
| 4 | 60 | 4 | 2 | 4 | 4 |
| 5 | 70 | 1 | 1 | 4 | 4 |
| 6 | 70 | 3 | 2 | 3 | 2 |
| 7 | 65 | 2 | 2 | 4 | 3 |
| 8 | 60 | 2 | 1 | 4 | 3 |
| 9 | 60 | 1 | 1 | 4 | 3 |
| 10 | 35 | 1 | 3 | 3 | 3 |
| Mean ±SE | 63±3.51 | 1.9±0.31 | 1.7±0.21 | 3.8±0.13 | 3.3±0.21 |

Kumar (2016) and Kaur (2017) reported the mean duration of surgery for straight IILN in dogs as 81.66 ± 6.73 and 76.25 ± 3.48 respectively. The decrease in duration of surgery over the period of time in the same institute despite facing many technical difficulties in the present study, indicates the increased experience and skill of surgeons.

Kaur (2017) observed status of fracture reduction and status of fracture fixation 3.11±0.20 and 3.50 ± 0.23 respectively. These findings of the present study are not much different from those reported while utilizing straight IILN in dogs.

Raghunath (2002) compared interlocking nailing technique and dynamic compression plating and found greater amount of stability in interlocking nailing technique. Yadav (2005) observed good status of reduction and fixation intra-operatively in all the groups treated with interlocking nailing technique.

**4.2.4: Post-operative observations**

Out of 10 cases of dogs, whose fractures were fixed with ACIILN technique, 9 were presented for postoperative follow-up. Case no.8 was lost to follow up. The case nos. 7 and 9 had multiple fractures. Case no. 7 had open tibio-tarsal avulsion fracture of contra-lateral limb and pelvic fracture along with femur fracture. Another case (no. 9, had additional fractures of pelvis and tibia of the same limb along with femur fracture. The case no. 9 was also diagnosed with sciatic neuropathy post-operatively. As the animal was recumbent in preoperative period, correct assessment of nerve function could not be ascertained beforehand but no damage to sciatic nerve occurred during surgery. In case no. 7, post-operative gait abnormality was considered to be because of combined effect of multiple fractures. Therefore, these cases (7, 8 and 9) were omitted for discussion for many part of this chapter except radiological observations.

Though the pet owners were suggested to bring the patients after every 15-day interval postoperatively, the compliance was very poor even after frequent reminders. Consequently, there was no uniformity in postoperative reappraisal days of these cases. Hence, in postoperative results and discussion, only two days of observations have been included, i.e. implant fixation day (IFD) and final reappraisal day (FRD). However, efforts were made to take regular reappraisals telephonically and so description of results also included those accounts at places.

The scores of inflammation, pain and muscle atrophy of the affected limb and overall subjective assessment of limb function on IFD and FRD has been summarized in table no 18.

**Table 18: Miscellaneous clinical and orthopaedic observations in dogs with femoral fractures repaired with ACIILN**

| Case no. | FRD | Inflammation | | Pain | | Muscle atrophy |
|---|---|---|---|---|---|---|
| | | IFD | FRD | IFD | FRD | FRD |
| 1 | 36 | 2 | 0 | 3 | 0 | 0 |
| 2 | 15 | 2 | 0 | 2 | 1 | 0 |
| 3 | 30 | 3 | 0 | 2 | 0 | 0 |
| 4 | 16 | 2 | 0 | 2 | 0 | 0 |
| 5 | 134 | 2 | 0 | 2 | 0 | 0 |
| 6 | 69 | 2 | 0 | 2 | 1 | 1 |
| 10 | 25 | 3 | 0 | 2 | 0 | 0 |
| Mean ±SE | | 2.3±0.18 | 0 | 2.1±0.15 | 0.28±0.18 | 0.14±0.14 |

Inflammation, pain, and muscle atrophy was scored from 0-3. Inflammation ranged from 2 to 3 with a mean score of 2.3±0.18 on IFD and decreased to 0 on FRD. Inflammation at fracture site is expected to decrease gradually in cases undergoing uneventful fracture healing. Kumar (2016) and Kaur (2017) also noted the same pattern in dogs subjected to femoral fracture repaired with straight ILN leading to disappearance of inflammation in all cases at FRD.

Score of pain ranged from 2 to 3 on IFD with a mean score of 2.1 ± 0.15 and at FRD it ranged from 0 to 1 with a mean score of 0.28 ± 0.18. Pain also decreased postoperatively in all cases but it persisted until FRD in two cases. Pain was exhibited by case nos. 2 and 6 during manipulation of limb even at the last reappraisal day. In one of the case (no. 2), it may be due to early FRD of case (day 15). In other (case 6), the exact cause of pain couldn’t be ascertained as there was no associated inflammation at surgical site. However, the dog kept its limb in abnormally extended position with stifle in a slight external rotation throughout the post-operative period. However, the weight-bearing on this limb was full but still mild muscle atrophy was also noticed in this case at FRD. The nervous examination also revealed no abnormality.

Braten and Rossroll (1995) in a case study of 116 human patients treated with reamed intramedullary nailing reported that prior to nail removal, hip and knee pain persist in 26 and 20 per cent cases respectively.

Kumar (2016) also reported similar findings where mild pain was evidenced by three dogs of IILN group with a mean score of pain 0.33 ± 0.16 at FRD. Muscle atrophy was also reported in 4 cases out of 9 with a mean score of 1 ± 0.44. Non-union of bone and instability of the bone implant construct were reported to be the cause for these problems. Kaur (2017) also reported mild pain in two out of nine cases and significant muscle atrophy in two cases at FRD in another similar study on dogs. These were reported to be because of concurrent vertebral fracture in one case and rotational instability of distal fragment in another case.

### 4.2.6: Status of weight-bearing

The weight-bearing status of the patients was assessed on a 10-point scale as described earlier in table no 4 of chapter 3. Higher number on point scale indicated excellent weight-bearing and vice-versa. Both pre and post-operative status of weight bearing status of weight-bearing were taken into considerations for comparative evaluation of results (Table 19).

**Table 19: Pre and post-operative weight-bearing scores of dogs**

| Case no | FRD | IFD score | FRD score |
|---|---|---|---|
| 1 | 36 | 0 | 8 |
| 2 | 15 | 0 | 4 |
| 3 | 30 | 1 | 8 |
| 4 | 16 | 3 | 5 |
| 5 | 134 | 0 | 10 |
| 6 | 69 | 1 | 8 |
| 10 | 25 | 1 | 10 |
| Mean± SE | | 0.85± 0.40 | 7.57±0.87 |

The scores of weight-bearing on IFD varied from 0-3 with a mean of 0.85±0.40. The representative photographs of pre-operative status of weight-bearing in dogs is given in the Fig. 4

| **Fig 4**: **Pre-operative status of weight-bearing in dogs with femoral fractures repaired with ACIILN** | |
|---|---|
|  |  |
| Limb not touching the ground in case5 | Toe touching ground occasionaly in case6 |

The weight-bearing gradually improved in all cases in the postoperative period and the score varied from 4-10 with a mean of 7.57±1.21 on FRD. The representative photographs of post-operative status in dogs is given in the Fig. 5.

In case no. 6, though the weight-bearing was good but the dog kept its lower limb in exaggerated extension with slight external rotation of stifle throughout the postoperative period and unexplained pain persisted in this case even up to FRD at 69 days. Newton and Nunamaker (1985) described that this deformity could be associated with rotation of fractured fragments and radiographically characterized by change in neck-shaft angle and orientation of head of femur and patella. But none of these changes were evident during radiographic examinations. The implant was removed in this case on 69$^{th}$ post-operative day in an attempt to reach any conclusion about the cause of pain. Though the patient was not presented thereafter but upon telephonic feedback, owner told about marked improvement in the limb function. Thus, in retrospection it could be hypothesized that the prolonged pain and abnormal gait in this case might be because of sensitization of sciatic nerve due to adjacent tissue reaction in response to longer end of the ACIILN protruding out of pin-insertion site and impinging on them. However, in many other case where similarly long ACIILN were used didn't exhibit any such problems.

**Fig 5. Post-operative status of weight-bearing in dogs with femoral fractures at different post-operative intervals repaired with ACIILN**

| | |
|---|---|
|  |  |
| Paw touching the ground frequently in case1 on $35^{th}$ day (weight bearing score 8) | Toe touching the ground frequently in case 5 on $30^{th}$ day (weight bearing score 5) |
|  |  |
| Paw touching regularly in case 5 on $134^{th}$ day (weight bearing score 10) | Paw touching the ground occasionally in case 4 (weight bearing 5) on $16^{th}$ day |

**Fig 6. Post-operative complications in weight-bearing of dogs with femoral fractures repaired with ACIILN**

Keeping of limb in outward direction on 56th day in case6

Absence of knuckling reflex on 29th day in case9

### 4.2.7: Goniometric observations

The range of motion of joints improved in all the cases in the postoperative period and by the time of final appraisal day, these were close to normal and comparable to that of contra-lateral limb in most cases. Largely, there was direct correlation with improvement in the status of weight-bearing and the normalization of the range of joint motion.

**Table 20: Pre and post-operative range of joint motions (in degree angle) in dogs with femoral fractures repaired with ACIILN**

| | Stifle (Extension angle) | Stifle (Flexion angle) | Hock (Extension angle) | Hock (Flexion angle) |
|---|---|---|---|---|
| IFD | 135.43±0.26 | 66.43±6.08 | 162±2.93 | 61±6.88 |
| FRD | 140.71±2.75 | 60.86±6.43 | 166.57±3.24 | 59.14±6.83 |
| Contra-lateral limb at IFD | 143.57±5.11 | 59.71±6.23 | 170.28±3.15 | 55.86± 8 |

### 4.2.5: Radiographic observations:

Based on radiographic observations, the fractures were found to be involving mainly the mid diaphysis (9) of femur; in one case the fracture was slightly distal diaphyseal (case no. 4). Fracture types varied from simple transverse (3) to short (3) or long (3) oblique and wedge (1) fracture.

**Fig. 7: Pre-operative radiographs of femoral fractures in dogs selected for repair with ACIILN**

| | | |
|---|---|---|
|  |  |  |
| Case no.1: Closed complete mid-diaphyseal short oblique fracture of left femur | Case no. 2: Closed complete long oblique mid diaphyseal fracture of right femur | Case no. 3: Closed complete mid-diaphyseal transverse fracture of right femur |
|  |  |  |
| Case no.4: Closed complete distal-diaphyseal transverse fracture of left femur | Case no. 5: Closed complete mid diaphyseal transverse fracture of left femur | Case no. 6: Closed complete distal long oblique fracture of left femur |

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Case no. 7: Closed complete mid-diaphyseal short oblique fracture of right femur</td><td>Case no. 8: Closed complete distal diaphyseal wedge fracture of right femur</td><td>Case no. 9: Closed complete mid-diaphyseal short oblique fracture left femur</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Case no. 10: Closed complete distal diaphyseal transverse fracture of right femur</td></tr>
</table>

In all the fractures fixed with ACIILN, uneventful ‘bridging osteosynthesis’ was recorded that was characterized by classical radiographic features of ‘Secondary fracture-healing’. Indirect (secondary) bone healing occurs in fractures in which some movement is possible between fracture fragments because of a lack of rigid fixation and characterized by callus formation. The fracture ends were initially stabilized by an intermediate stage of soft (relatively radiolucent) and subsequently hard osseous (radiopaque) callus.

The earliest day at which sufficient amount of callus at fracture site could be visualized was $16^{th}$ day and that was the first radiographic reappraisal day of that case. Variable degree of bridging callus was observed at different postoperative intervals in different dogs. Distribution of callus over different aspects of bones varied. More amount of callus formed over surfaces of bones under greater compression loads. In this study it was observed that in most of the cases (case no.1, 5, 6, 9 and 10) more amount of callus formed at medial and caudal (concave) surface of femur indicating less amount of stability at these surfaces. More callus on concave surface of bones can be explained by the fact that the resulting greater compression on that surface is known to cause a negative charge that stimulates osteoblastic activity, while tension causes a positive charge, stimulating osteoclastic activity (Newton and Nunamaker 1985).

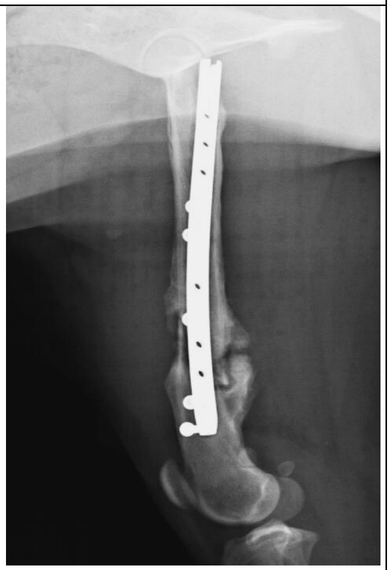
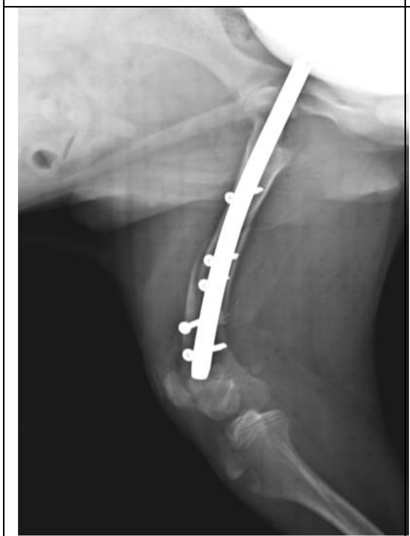
The radiographic evidence of fracture healing was seen in all the cases except in case no. 7 where delayed union of bone observed. Durall and Diaz (1996) observed radiographically fracture healing in interlocking nailing technique, usually between 8 and 16 weeks after surgery. Various factors affects the rate and amount of callus formation such as age, amount of rigidity achieved during implant fixation, health and nutritional status of animal. In young animals rate of callus formation or fracture healing is fast.

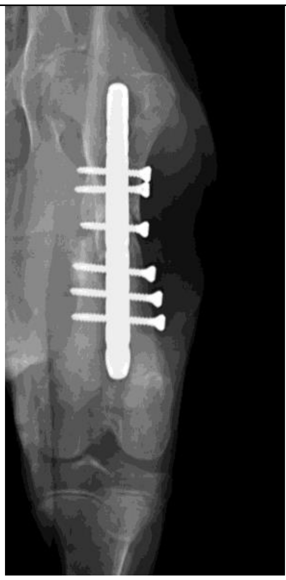
Strain is the deformation of a material when a given force is applied. The bone is subjected to various kinds of muscular and environmental disruptive forces/strain. Interfragmentary-strain stimulates osteoprogenitor cells and undifferentiated mesenchymal cells in the periosteum to form callus. Perren’s strain theory states that when strain is <2 percent, primary fracture-healing can occur; when strain is between 2-10 percent, the fracture heals by secondary fracture healing; when strain is >10 percent, callus in the fracture gap ruptures and nonunion develops.

In four out of ten cases (1, 3, 4 and 10) the proximal end of ACIILN reached just above the trochanteric fossa. In one case (no. 5), nail was at the level of trochanteric fossa whereas, in remaining cases (nos. 2, 6, 7, 8 and 9), the nail end extended 1-2cm beyond the trochanteric fossa. Distally, the nail end reached just above the level of curved distal metaphysis in most cases; in one case (no. 4), the nail crossed the distal cranial cortex adjacent to trochlea. In another case (no. 10) nail penetrated the cranial cortex of bone just above the trochlea. This might be due attributed to inappropriate reaming as explained in intraoperative observations section of this chapter.

Pictorial depiction of radiographic observations in representative cases of uneventful healing in ACIILN group is given below in fig.8.

**Fig. 8. Post-operative representative radiographs of uneventful healing of femoral fractures of dogs repaired with ACIILN**

| | | |
|---|---|---|
|  |  |  |
| Immediately after surgery- good anatomical reduction and stability of fracture in case no.1 | Day 17- little amount of periosteal callus; radiolucent fracture line still present . | Day 39 – Organisation of periosteal callus seen with continuation of cortical line at fracture site. |
|  |  |  |
| Surgery day- Misdirection of one of the distal (penultimate) transcortical screw | Day 7- Periosteal reaction seen at caudal side of cortex and little instability at fractured fragments. | Day 37- large periosteal callus. |

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Immediately after surgery in case no. 9</td><td colspan="2">25 days PO-Large amount of external periosteal callus at caudal and medial cortex of bone</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Immediately after Surgery – good anatomically reduction in case no.5</td><td>Day 30- implant is stable and little amount of external bridging callus.</td><td>Day 134- Remodelled callus</td></tr>
</table>

Over the time, callus remodeling occurred to restore cortical and medullary continuity of bone in many cases.

Various technical faults and post-operative complications were observed in many cases during the period of study. Representative pictures of these complications are given below in the fig 9.

**Fig. 9. Post-operative radiographs depicting various technical faults and complications in cases of dogs with femoral fractures repaired with ACIILN**

| | | |
|---|---|---|
|  |  |  |
| Mal-alignment in one of the distal screw(case no. 9 ) | Inappropriate length of screws (case no.7) | Penetration of physeal plate and crossing of trochlea (case no.4) |
|  |  |  |
| Penetration of distal cranial cortex (case no.10) | Delayed union (mild periosteal callus reaction 103 days PO) and osteolytic changes in bone (case no.7) | Stress protection syndrome (case no. 6) |

In six cases (Case no. 1, 2, 6, 8, 9 and 10), one or two locking screw failed to engage the cannulation of ACIILN during placement but this could not be detected during the time of surgery. Post-operative radiographs however, revealed such faults. The transverse locking screws went around the ILN rather than passing through its hole in such cases. In all the cases, the mal-alignment occurred at most distal hole except in one case (no.6) where penultimate screw was mal-aligned. Similar findings were also reported by Kaur (2017), while utilizing straight IILN where mal-alignment of screws observed in 4 out of 12 cases. Arican et al. (2017) also reported that six ILNs out of 26 cases were not locked correctly at distal site due to misdirection of screws but there was no misdirection of screws at proximal site. Durall and Diaz (1996) noted complications in 11 cases out of 15 dogs repaired with interlock nail consisted of loosening of the distal screw. These results are in line with those observed by Kumar (2016) and Kaur (2017). Yadav (2005) reported various screw related complications like missing of screws, bending and breakage of screws. However, none of these complications hinder stability or healing process of bone.

In one of the case (no.4) nail crossed the physeal plate noticed immediately after surgery. Though the post-operative fracture healing and angulation of limb was good but there was shortening of limb (4cm compared to contra-lateral limb).

In one of the case despite being anatomically contoured, the nail penetrated the cranial cortex (case no. 10) but the animal didn’t show any sign of lameness in the post-operative period. Kumar (2016) and Kaur (2017) also reported inadvertent penetration of distal cortex of different degrees while utilizing straight IILN with or without clinical significance.

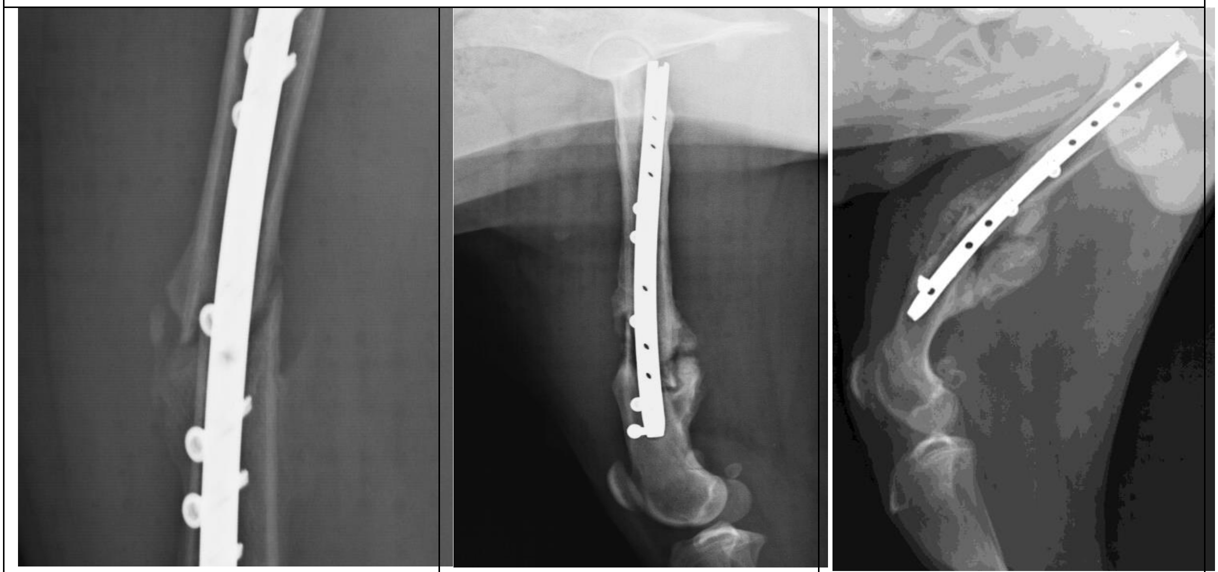
Delayed union was observed in one case (no. 7). Mild external periosteal callus was visible in this case along with osteolytic changes at implant interface site at FRD on 103th day. A similar osteolytic change was seen in case no. 6. Osteolysis is defined as the process of progressive destruction of bony tissue, characterized on serial radiographs as progressive radiolucent lines or cavitation at the implant-bone interface.

Saleh et al. (2004) opined that osteolysis is a multifactorial process stemming from host, prosthesis and surgical factors. Billions of submicron wear particles are generated at material interfaces that cause osteolysis. Arican et al. (2017) also reported a case of osteolytic changes in one tibia out of 26 long bone fractures repaired with IILN.

**Table 21: Final radiographic observations and clinical outcome in dogs with femoral fractures repaired with ACIILN**

| Case no. | Radiographic Observations | | Final clinical outcome |
|---|---|---|---|
| | Size of callus | Outcome (days) | |
| 1 | Moderate | Healing in progress (39) | Excellent |
| 3 | Minimal | Healing in progress (30) | Good |
| 4 | Large | Complete union (16) | Fair |
| 5 | Large | Complete union (30) | Excellent |
| 6 | Large | Complete union (37) | Fair |
| 7 | Minimal | Delayed union (110) | Poor |
| 9 | Large | Complete union (29) | Poor |
| 10 | Large | Complete union (25) | Excellent |

**Fig. 10. Post-operative representative radiographs depicting range of callus during healing of femoral fractures repaired with ACIILN in dogs**

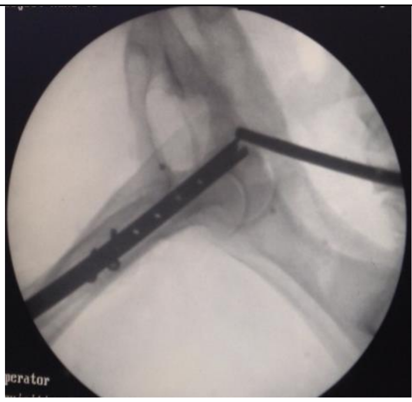


| Day30- minimal amount of periosteal callus in case no. 3 | Day 17–moderate amount of periosteal callus in case no.1 | Day 29- Large amount of periosteal callus in case no. 9 |
|---|---|---|

In most of the cases, fracture healing occurred by large callus formation. This is consistent with the findings of Kumar (2016) who reported large-sized callus in most of the cases of femoral fractures repaired with straight ILN. However, this varies with the findings of Hansda et al. (2012) and Asif et al. (2011) who reported fracture healing with static IILN with minimum callus formation. This may be attributed to various factors like type of fracture, status of reduction, status of fixation, uncontrolled activity of the patient and age of the patient.

**Implant removal:** Implant was removed in 3 cases (case no. 6, 7 and 9) under general anesthesia. Fluoroscopy was utilized only in one case to detect the position of proximal end of nail.

**Fig 11: Fluoroscopy-assisted removal of ACIILN in dogs**



Insertion of conical bolt into interlocking nail under C Arm during removal of implant (ACIILN 7)

**Fig.12: Surgical removal of ACIILN in dogs**

|  |  |  |
|---|---|---|
| Insertion of conical bolt at proximal end of nail | Large amount of callus present around fracture site | Removal of screws |

### 4.3: Comparative evaluation of different techniques for fixation of femoral fractures in dogs:

Different techniques were used for fixation of femoral fractures during the period of study as described in table number 2 of Chapter 3. For comparison purpose however, only ACIILN and end-threaded positive profile self-tapping screw ended pinning (ETP)/ Admit pins were included in this study because both techniques were used for more or less similar kind of fractures i.e. diaphyseal fractures. Most distal and proximal fractures were excluded from the study. ETP was applied in 16 diaphyseal fractures of femur. Among these 16 cases only 3 cases of ETP were finally chosen for comparison.

#### 4.3.1: Brief case-history of dogs and types of fractures treated with positive profile end-threaded pinning

The brief case history of dogs under the positive profile ETP group is given in the table 22. The case history revealed that the age of the dogs in this group ranged from 4-8 months and body-weight from 10-18 kg. All the three dogs were male. Fractures were closed type in all the cases. The overall time lag from trauma to internal fixation of fracture (TIF) ranged from 3-6 days.

**Table 22: Brief anamnesis and clinical findings of dogs with femoral fractures repaired with ETP**

| Case no | Age (months) | Sex | BW (kg.) | Cause of fracture | Fracture type | Breed | TIF (Days) |
|---|---|---|---|---|---|---|---|
| ETP1 | 6 | M | 15 | Automobile accident | Closed | ND | 6 |
| ETP2 | 4 | M | 10 | Automobile accident | Closed | ND | 3 |
| ETP3 | 8 | M | 18 | Automobile accident | Closed | ND | 3 |

Based on radiographic observations, the fracture types varied from simple transverse (1), long oblique (1) and wedge (1) but all involved mid-diaphyseal area of femur.

Comparative evaluation of both the techniques was done on the basis of observations of two days i.e. IFD (implant fixation day) and FRD (final reappraisal day).

**Fig. 13: Pre-operative radiographs of femoral fractures in dogs selected for repair with ETP**

ETP 1: Closed complete spiral diaphyseal fracture of left femur

ETP 2: Closed complete transverse mid diaphyseal fracture of right femur

ETP 3: Closed wedge fractures of left femur diaphysis

### 4.3.2: Fracture assessment scores, implant selection and placement of positive profile self-tapping screw end threaded pins/Admit pins

The fracture assessment scores (FAS) for individual cases ranged from 13.5-23 in ACIILN group (table no. 16) and 21-23 in positive profile ETP group. ETP of 4.5-3.5mm and 5.5-4.0mm diameters were used to repair femoral fractures.

**Table 23: Fracture assessment score and implant selection in ETP group**

| Case no. | FAS (30)<br>M/B/C | Implant |
|---|---|---|
| ETP1 | 22.4 (8/5.4/9) | 5.5-4.0-2(22) |
| ETP2 | 23 (8/6/9) | 4.5-3.5 |
| ETP3 | 21 (7/6/8) | 5.5-4-2(22) |

In adjunct to ETP, cerclage wiring was done in 2 cases to improve fracture fixation as the fracture was comminuted in ETP 3 and long oblique along with long fissures in ETP 1. ETP of size 4.5-3.5mm was used in 10 kg dog, while 5.5-4.0mm in 15-18kg dogs.

### 4.3.3: Intra-operative observations

Intra-operative observations of ACIILN group are given in table17 and that of ETP group in table 24.

**Table 24: Intra-operative observations in cases of femoral fractures repaired with ETP**

| Case no. | Duration of surgery (In min.) | Extent of manipulation and soft tissue damage | Degree of technical difficulty | Status of fracture reduction | Status of fracture fixation |
|---|---|---|---|---|---|
| ETP1 | 43 | 1 | 1 | 3 | 4 |
| ETP2 | 35 | 1 | 1 | 3 | 3 |
| ETP3 | 40 | 1 | 1 | 2 | 2 |
| Mean ± SE | 39.33 ± 3.82 | 1 | 1 | 2.6 ± 0.14 | 3 ± 0.19 |

The application technique of ETP was as per Chanana (2014).The ETP were seated within the bone in a slightly different manner than Steinmann pinning technique. Instead of just pushing the pin straight, the distal end of ETP was inserted through the medullary cavity by turning it clockwise as if fixing a screw in the metaphysis.

The mean duration of surgical procedure in minutes was markedly higher in ACIILN group (63±3.51) than that of ETP group (39.33 ± 3.82). It was because the placement of ACIILN technique involved greater number of surgical steps than ETP. The mean score for degree of technical difficulty was also higher in ACIILN group (1.7 ± 0.21) as compared to positive profile ETP group (1). The mean score of extent of manipulation and soft tissue damage was also more in ACIILN group (1.9 ± 0.31) as compared to positive profile ETP group(1). Longer duration of surgery and more adjacent tissue trauma in ACIILN group led to increase soft tissue damage.

The mean scores for status of fracture reduction was 3.8± 0.13 in ACIILN group and 2.6 ± 0.14 in positive profile ETP group. The mean score for status of fracture fixation were 3.3 ± 0.261 in ACIILN group and 3 ± 0.19 in ETP group. Thus, in the present study, the ACIILN technique proved to be significantly more time-consuming, required greater exposure of bone and more manipulation of tissue. However, the status of fracture fixation and reduction was better than positive profile ETP.

These findings are in line with those of Kumar (2016) and Kaur (2017) who opined that in general, the technique of interlocking nailing was associated with relatively greater surgical trauma compared to simple intramedullary pinning techniques including ETP as greater exposure of the surgical site was required for the insertion of screws in the proximal as well as distal segments.

### 4.3.4: Clinical and orthopedic observations

The scores of inflammation, pain, muscle atrophy, weight-bearing on the affected limb and assessment of limb function on IFD and FRD has been summarized in table 18 &19 for ACIILN group and table 25 for ETP.

Inflammation decreased from mean score of 1.66± 0.58 at IFD to 0 at FRD. Pain decreased from 2 ± 0.58 at IFD to 0.66±0.33 at FRD. Pain was present in ETP 2 and ETP 3. It was associated with migration of nail and thereby impinging on soft tissues. No muscle atrophy was observed in any of the ETP cases. In ACIILN group there was no inflammation at FRD. Mean score of pain and muscle atrophy was 0.28±0.18 and 0.14±0.14 respectively.

**Table 25: Pre and post-operative observations of dogs in cases of femoral fractures repaired with ETP**

| Case no. | FRD | Inflammation | | Pain | | Muscle atrophy FRD | Weight bearing | |
|---|---|---|---|---|---|---|---|---|
| | | IFD | FRD | IFD | FRD | | IFD | FRD |
| ETP 1 | 28 | 1 | 0 | 1 | 0 | 0 | 0 | 8 |
| ETP 2 | 22 | 3 | 0 | 3 | 1 | 0 | 2 | 6 |
| ETP 3 | 35 | 1 | 0 | 2 | 1 | 0 | 0 | 9 |
| Mean ± SE | | 1.66 ±0.58 | 0 | 2 ± 0.58 | 0.66 ± 0.33 | 0 | 0.6 ±0.67 | 7.6 ±0.95 |

All the three cases of ETP group showed gradual improvement in weight-bearing on final reappraisal day. The pre-operative weight-bearing scores in ACIILN group ranged from 0 to 3 (0.85±0.40) and 0 to 2 (0.6 ± 0.67) in ETP group. At FRD, the mean weight-bearing scores of positive profile ETP group was recorded as 7.6 ±0.95 and 7.57± 0.87 in ACIILN group. Weight-bearing was equally comparable in both the groups at FRD.

| **Fig. 14: Status of weight-bearing on the affected limb in ETP cases** | |
|---|---|
|  |  |
| Paw touching ground regularly in ETP 1 | Paw touching ground regularly ETP3 |

**4.3.5 .Radiographic observations:**

| **Fig. 15 : Post-operative radiographs of femoral fractures repaired with ETP** | |
|---|---|
|  |  |
| ETP 1: Immediate after surgery : good reduction and fixation of fracture | Day 28 PO: Moderate amount of external periosteal callus |

| | |
|---|---|
|  |  |
| ETP 2: Immediate after surgery- good anatomical reduction and fixation of fracture | Day 22 after PO: periosteal callus reaction seen along with slight migration of pin |
|  |  |
| ETP 3: Immediate after surgery- faulty fixation (abnormal angulation) | Day 35: Periosteal callus reaction seen along with slight pin migration. |

All the fractures fixed with positive profile ETP healed with formation of external periosteal callus i.e. secondary healing. All the animals presented on final reappraisal day showed radiographic signs of bone healing. Amount of callus varied in different cases. Two out of three cases (2 and 3) showed proximal migration of pin. Fixation fault was observed in ETP 3 and medial deviation observed immediately after post-operative radiograph. These findings are in consistent with findings of Kumar (2016) and Kaur (2017) who also reported migration of many ETPs against none of ILN in their studies. This shows that interlocking nail counters the disruptive biomechanical forces working on the bones more effectively than ETP. However, despite premature migration of pins in

ETP groups, the clinical outcome was good and the animals showed good recovery. This can be attributed to the relatively younger age of patients where healing progresses faster and thereby minimizes fracture complications.

**Range of size of callus:** The size of callus during healing was moderate (1) to minimal (2) whereas, callus was relatively larger in ACIILN group in most cases. This finding is in contrast with Kaur (2017) where size of callus was reported to be larger in ETP group as compared to IILN.

**Table 26: Final radiographic observations and clinical outcome of dogs in cases of femoral fractures repaired with ETP**

| Case no. | Radiographic observations | | Final clinical outcome |
|---|---|---|---|
| | Size of callus | Outcome(days) | |
| ETP 1 | Moderate | Complete union (28) | Good |
| ETP 2 | Minimal | Healing in progress (22) | Good |
| ETP 3 | Minimal | Healing in progress (35) | Good |

**Implant removal:** ETPs was removed in two cases (1and 3) under general anaesthesia. A small incision was given in the skin over pin insertion site. The removal entailed fixing of the proximal pin-end in the Jacob's chuck of Steinmann pin driver and turning it anticlockwise so as to unscrew its distal end from metaphysis and then through proximal portion of bone.

### 4.3.7: Goniometric observations

**Table 27: Range of joint motions (in degree angle) in dogs in cases of femoral fractures repaired with ETP**

| | | Stifle (Extension angle) | Stifle (Flexion angle) | Hock (Extension angle) | Hock (Flexion angle) |
|---|---|---|---|---|---|
| Positive profile ETP | IFD | 139.5±6.27 | 48.375±4.04 | 163.75±1.37 | 50.62±4.09 |
| | FRD | 147.86±6.06 | 47.86±4.21 | 165.14±2.98 | 46.71±5.13 |
| | Contra | 155.25±3.85 | 43.125±2.94 | 170.25±2.93 | 44.37±4.06 |

The range of motion of joints improved gradually in most of the cases in the postoperative period, and it was close to that of contralateral limbs by the FRD.

**Chapter 5**

# Summary and Conclusions

Femur is the most common fractured long bone in dogs. Different internal fixation techniques such as intramedullary pinning, bone plating, intramedullary interlocking techniques are used to repair femoral fractures. These techniques have their own merits and demerits. Many factors affect the selection of a technique for a specific situation. From the biomechanical point of view, the intramedullary interlocking nailing counteracts all the forces (axial, rotational and bending) act on the bone. It was observed, that the conventionally used interlocking nails were straight in shape but the diaphysis of dogs were curved with convex surface facing cranially. Besides, the femoral shaft of mature dog tapers to mid-shaft isthmus and then flares to distal metaphysis. Hence, it was difficult to place straight intramedullary implants in such a curved distal segment of femoral bones without compromising the anatomical alignment of fragments. So the current study was conducted to evaluate the specially-designed anatomically contoured intramedullary interlocking nailing (ACIILN) for fixation of femoral fractures in dogs. The study also compared this technique with Positive profile End threaded screw ended pinning (ETP) for fixation of similar kinds of fractures in dogs. Besides, a brief study was also undertaken to record the regional occurrence of fractures in dogs.

The study was conducted on the clinical cases of dogs presented to the Department of Veterinary Surgery and Radiology, DGCNCOVAS, CSKHPAU, Palampur, India from January 2018 to April 2019. The clinical cases of fractures in dogs were investigated in detail for recording of a number of variables like sex and age, the cause of fracture, the affected bone/s and the type of fractures etc. for drawing the pattern of occurrence of fractures. The different bones involved with fractures were recorded. Fractures of all the long bones in dogs were classified on the basis of the communication of fracture line to the outside environment as open or closed, on the basis of the extent of damage to the bone as complete or incomplete and on the basis of affected side, whether right or left. These details were categorized and analyzed suitably to generate data base of the regional occurrence of fractures in dogs.

In the period of study, 4619 new clinical cases were registered in the Teaching Veterinary Clinical Complex; Out of these 1839 were presented in Department of Surgery and Radiology. Out of these 1839 clinical cases, 262 cases of fractures recorded in different animal species. Out of 1839 cases, 1337 (72.70%) were dogs.

Sex-wise, large number of male dogs were presented (74.50%) for fracture treatment. Incidence of fracture was more in male dogs was (17.69%) and it was (10.7%) in female dogs. Majority of fractures in dogs occurred in juvenile group (51.47%) followed by adult (39.21%) and senile (9.31%). The major known cause of fractures in dogs was determined to be automobile accidents (47.06%). Among all bones, femur was most commonly affected (24.76%), followed by tibia/fibula (16.35%), radius/ulna (15.88%) and humerus (10.74%) in dogs.

In femoral fractures, right side was more commonly affected (62.83% as against 43.40%); (3.77%) fractures were in bilateral limb; (92.40%) were complete and all of them were closed type. In tibia/fibula, the right side was more commonly affected (62.86% as against 37.14%); majority of the fractures were complete (91.43%); (20%) of tibia fractures were open. In humerus, right side was affected more (56.28% as against 43.48%); majority of the fractures were complete (91.30%) and (8.69%) fractures were open. In radius/ulna, left side was more commonly affected (50% as against 44.11%); (5.88%) fractures were in bilateral limb; all fractures were complete and (5.88%) fractures were open.

The ACIILN technique was used in diaphyseal fractures of femur to for its clinical evaluation. This technique was used in fracture-fixation of 10 dogs of different age, sex, body-weight and breeds. Pre-operative observations recorded were; anamnesis and signalment, basic clinical, radiological, haemato-biochemical and orthopedic examinations. On the basis of pre-operative observations, fracture assessment scores (FAS) were obtained by adding mean scores of mechanical, biological and clinical factors of individual cases. Fifty-three cases of femoral fractures were presented during period of study but ACIILN technique was applied in 10 cases. Selection of patient for application of this technique was done on the basis of location of fractures (only diaphyseal fractures were treated with ACIILN), length of bone and length of fractured segments. Pre-operatively most probable size of implant was selected on the basis of radiograph. Intra-operative observations were duration of surgery, extent of manipulation and soft tissue damage, degree of technical difficulty, the status of fracture reduction and fixation, complications and any other remarkable observations. Post-operative observations included clinical, orthopaedic, radiological and goniometric examinations at the time of reappraisal of the patient. Additionally, pain, inflammation, muscle atrophy and healing of surgical site were also recorded.

ACIILN was done in 10 dogs and the technique was found suitable for fixation of diaphyseal fractures of femur. The age of the dogs ranged from 4-15 months and weight from 10-30 kgs. The overall time lag from trauma to internal fixation of fracture (TIF) ranged from 1-6 days. The FAS scores for individual cases ranged from 13.5-23. The fractures were fixed with anatomically contoured IILNs (made of 316L stainless steel). ACIILN were developed by the department for specific use in dogs'. Nails were bent at an angle of 8° for better alignment in curved diaphysis of canine femur with convex surface facing cranially. Different trials were done on different dogs' femur and it was found that bone of dog cranially bent at 6 to 11°. So nail with a mean angle of 8° was devised to repair femoral fractures in dogs. The nails' diameter ranged from 5 to 7 mm and the lengths from 10 to 17 cms, which accommodated 2.0 mm orthopaedic screws in cases of 5 mm nails and 2.7 mm screws in cases of 6 and 7 mm nails.

The duration of surgery for application of ACIILN ranged from 35-75 minutes (63± 3.51). Extent of manipulation and soft tissue damage as well as the technical difficulty ranged from 1-3 with a mean of 1.9 ± 0.18 and 1.7 ± 0.20 respectively. Drilling of hole over the sloping surface of femur at distal fragment was the main difficulty encountered during surgery. In few cases a bone tunnel of 2mm greater than diameter of nail rather than usual 1mm was formed to properly seat the nail in bone. The fracture reduction and fixation was good with a mean value of 3.8 ± 0.13 and 3.3 ± 0.21 respectively.

The inflammation score was 0 on final reappraisal day (FRD) compared to 2 to 3 (2.3 ± 0.15) on internal fixation day (IFD). Similarly, the pain-scores ranged from 0 to 1 (0.28±0.18) on FRD as compared to 2 to 3 (2.1±0.15) on IFD. Mild muscle atrophy was noticed in one case on FRD. The scores of weight-bearing ranged from 4 to 10 (7.57± 0.87) on FRD as compared to 0 to 3 (0.85 ± 0.40) on IFD. Two cases with multiple limb fractures along with pelvic fractures were not included in this part of study.

In all of the fractures fixed with ACIILN (8 out of 9), uneventful 'Bridging osteosynthesis' was observed characterized by classical radiographic features of 'Secondary fracture-healing'. The size of callus during such healing process however, varied from case to case. Minimal amount of callus were noticed in 2 cases, moderate in 2 and large in 5 cases. In most of the cases more callus formed at medial and caudal surface of bone.

Various technical faults and postoperative complications were seen in many cases. In 6 out of 10 cases, screw did not engage the cannulation of ACIILN. This mal-alignment was observed at distal screws. In 2 out of 10 cases, inadvertent penetration of distal metaphysis during intramedullary reaming occurred. In one of the case nail crossed the physeal plate and there was limb shortening, while in other case where nail crossed the distal cranial cortex no signs of lameness observed and bone healed without any complications. In 2 out of 9 cases osteolytic changes were observed in bones.

In 5 out of 10 cases, the radiograph revealed that one or more screws were of inappropriate length in implant fixation. This was attributed to improper screw depth gauge.

The ACIILN technique was compared with positive profile ETP in femoral fractures of dogs. The ETPs were modified Steinmann pins having cancellous threads towards its distal screw end and trocar shape towards proximal end. Comparison was done on the basis of previously described pre-operative, intra-operative and post-operative observations. Coding of implants was done to easily understand the dimensions of implant.

In ETP group, the age of the dogs ranged from 4-8 months and body-weight from 10-18 kg. Fractures were closed type in all cases. The overall time lag from trauma to internal fixation of fracture ranged from 3-6 days in ETP group. The fracture types repaired with ETP varied from simple transverse (1), long oblique (1) and wedge (1). The fracture assessment scores (FAS) for individual 21-23 in ETP group. ETP of two diameters (4.5-3.5mm and 5.5-4mm) with different lengths were used for these fracture-repairs.

The duration of surgery (in minutes) was comparatively longer in ACIILN group (63±3.51 against 39.33±3.82 in ETP group). The mean scores of extent of manipulation and soft tissue damage were 1.9 ±0.31in ACIILN group and (1) in ETP group. The mean scores for degree of technical difficulty was 1.7 ± 0.21 in ACIILN group and (1) in ETP group. These were mainly because the placement of ACIILN involved greater number of surgical steps than ETP. The placement of ACIILN required relatively greater surgical exposure of the site.

The mean scores for status of fracture reduction were 3.8± 0.13 in ACIILN and 2.6 ± 0.14 in ETP group. The mean scores for status of fracture fixation were 3.3 ± 0.21, and 3 ±0.33 respectively.

Thus, the ACIILN technique proved to be significantly more time consuming, required greater exposure of bone and more manipulation of tissue. However, the status of fracture fixation and reduction was good in this group.

In ACIILN group, the preoperative inflammation scores were 2.3± 0.18 and in ETP group were 1.66 ± 0.58. No inflammation found at FRD in both the groups. Similarly, the preoperative pain-scores were 2.1 ± 0.15 in ACIILN group and 2 ± 0.58 in ETP group.

The muscle atrophy was recorded in one case in ACIILN group. But no muscle atrophy was seen in ETP group. The weight-bearing improved gradually in both groups postoperatively. At FRD, the mean weight-bearing scores of ACIILN group was found 7.57 ± 0.70 as against 7.6±0.95 in ETP group. Weight-bearing was equally comparable in both the groups at FRD.

In all the fractures fixed with ETP, uneventful ‘Secondary fracture-healing’ was observed. Most common complication recorded with ETP group was pin migration.

Keeping in view of all the above observation, it was concluded that -

- The regional incidence of fractures in dogs is 16 per cent with a distribution rate of 78 per cent among all species of animals presented to the Department of Veterinary Surgery and Radiology, Palampur.
- The distribution of fractures is more in Juvenile age-group but incidence is more in adult age group of dogs
- The major cause of fracture in dogs is automobile accidents and the femur is most frequently fractured long bone
- The anatomically contoured intramedullary interlocking nailing (ACIILN) technique can be used successfully for repair of diaphyseal femoral fractures in dogs.
- The misalignment of one or more screws with distal cannulations of ACIILN due to faulty drilling of holes is a major problem in its application
- The one screw each in proximal and distal segment of fracture provide adequate amount of stability to the femoral diaphyseal fracture.
- The technique of ACIILN is relatively more time-consuming and involves more tissue trauma than the end-threaded intramedullary pinning (ETP) technique for repair of femoral fractures in dogs.

# Literature cited


Arican M, Alkan F, Altan S, Parlak K and Yavru N. 2017. Clinical experience of interlocking nail stabilization of long bone fractures in dogs – A retrospective study of 26 Cases. *Israel Journal of Veterinary Medicine* 72 (2): 45-50

Asif MA, Dilipkumar D, Shivaprakash BV, Usturge SM, Kasaralikar VR and Raidurg R. 2011. Clinical evaluation of static and dynamic veterinary intramedullary interlocking nailing technique for femoral fracture repairs in dogs. *Indian Journal of Veterinary Surgery* 32(2): 94-98

Asma M. 2014. Osteo-synthesis Use in Dogs' Femur Surgical Fractures Repair: An Experimental and Comparative Study. *World's Veterinary Journal* 4(1): 06-10, 2014

Ben Ali LM. 2013. Incidence, occurrence, classification and outcome of small animal fractures: a retrospective study (2005-2010). *International Science Index, Animal and Veterinary Sciences* 7(3): 191-96

Bernard A, Diop A, Maurel N and Viguier E. 2001. An *in vitro* biomechanical study of bone plate and interlocking nail in a canine diaphyseal femoral fracture model. *Veterinary Surgery* 30: 397-408

Braten M, and Rossvoll T. 1995. Femoral shaft fractures treated by intramedullary nailing: A follow-up study focusing on problems related to the method. *Injury* 26(6): 379-383

Bruckner M, Unger M **and** Spies M. 2016. Early Clinical Experience with a Newly Designed Interlocking Nail System-Targon (®) Vet. *Veterinary Surgery.* 45(6): 754-63.

Burns CG, Litsky AS, Allen MJ and Johnson KA. 2011. Influence of locking bolt location on the mechanical properties of an interlocking nail in the canine femur.*Veterinary Surgery* 40(5): 522-30

Chanana M. 2014. Clinical evaluation of end threaded intramedullary pinning for management of long bone fractures in canines. *M.V.Sc Thesis,* Department of Veterinary Surgery and Radiology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India

Conceicao M, Santos L, Sembenelli G, Lima C, Rocha T, Minto B and Dias L. 2018. Interlocking nail combined with locking plate fixation for a distal diaphysis femur comminuted fracture in a dog. *Acta Scientiae Veterinariae* 46(1): 263

Dejardin LM, Lansdowne JL, Sinnott MT, Sidebotham CG and Haut RC. 2006. In vitro mechanical evaluation of torsional loading in simulated canine tibiae for a novel hourglass-shaped interlocking nail with a self-tapping tapered locking design. *American Journal of Veterinary Research* 67(4): 678-85

Dueland RT, Berglund L, Vanderby R and Chao EYS. 1996. Structural properties of interlocking nails, canine femora and femur-interlocking nail constructs. *Veterinary Surgery* (25): 386-96

Duhautois B. 2003. Use of veterinary interlocking nails for diaphyseal fractures in dogs and cats: 121 cases. *Veterinary Surgery* 32: 8-20

Durall I and Diaz MC. 1996. Early experience with the use of an interlocking nail for the repair of canine femoral shaft fractures. *Veterinary Surgery* 25: 397-406

Elzomor ST, Sheta EME, Farghali HA and Ashour AE. 2014. Prevalence of femoral fractures in dogs and cats. *Journal of the Egyptian Veterinary Medical Association* 74(2): 269-78

Endo K, Nakamura K, Maeda H and Matsushita T. 1998. Interlocking intramedullary nail method for the treatment of femoral and tibial fractures in cats and small dogs. *Journal of Veterinary Medical Science* 60(1): 119-122

Georgiadis GM, Minster GJ, Moed BR. 1990. Effects of dynamization after interlocking tibial nailing: an experimental study in dogs. *Journal of orthopaedic trauma* 4(3):323-30

Hansda P, Gahlod BM, Akhare SB, Dhakate MS, Upadhye SV and Panchbhai VS. 2012. Comparative evaluation of Steinmann pin, Kuntscher nail and interlocking nail for femur fracture repair in dog. *Indian Journal of Veterinary Surgery* 33(1): 53-54

Harasen G. 2003. Common long bone fractures in small animal practice — Part 1. *The Canadian veterinary journal 44(4):* 333–334.

Henry SL, Trager S, Green S, Seligson D. 1991. Management of supracondylar fractures of the femur with the GSH intramedullary nail: Preliminary report. *Contemporary orthopaedics* 22(6): 631-40.

Igna C, Schuszler L, Dascalu R, Sabau M and Luca C. 2011. Interlocking nail stabilization of diaphyseal long bone fractures. Initial experiences in six clinical cases. *Bulletin of University of Agricultural Sciences and Veterinary Medicine* 68(2): 165-170

Kaur J. 2017. Evaluation of interlocking nailing technique for fixation of long bone fractures in small animals. M.V.Sc. thesis. Department of Veterinary Surgery and Radiology, DGCN, COVAS, CSKHPKV, Palampur, India

Kumar H. 2016. Comparative evaluation of different techniques for femoral fracture fixation in canines. M.V.Sc. thesis. Department of Veterinary Surgery and Radiology, DGCN, COVAS, CSKHPKV, Palampur, India

Kushwaha RB, Gupta AK, Bhadwal MS, Kumar S and Tripathi AK. 2011. Incidence of fractures and their management in animals: a clinical study of 77 cases. *Indian Journal of Veterinary Surgery* 32(1): 54-56

Libardoni N, Costa D, Menezes FB, Cavalli LG, Pedrotti LF, Regina P, Kohlrausch, Minto BW and Silva MA. 2018. Classification, fixation techniques, complications and outcomes of femur fractures in dogs and cats: 61 cases (2015-2016) *Ciencia Rural* 48 (6)

Minar M, Hwang Y, Park M, Kim S, Oh C, Choi S and Kim G. 2013. Retrospective studies on fracture in dogs. *Journal of Biomedical Research* 14(3):140-144

Moses PA, Lewis DD, Lanz OI, Stubbs WP, Cross AR and Smith KR. 2002. Intramedullary interlocking nail stabilization of 21 humeral fractures in 19 dogs and one cat. *Australian Veterinary Journal* 80(6): 336-343

Muir P and Johnson KA. 1996. Interlocking intramedullary nail stabilization of a femoral fracture in a dog with osteomyelitis. *Journal of the American Veterinary Medical Association* 209(7): 1262-1264

Muir P, Parker RB, Goldsmid SE and Johnson KA. 1993. Interlocking intramedullary nail stabilization of a diaphyseal tibial fracture. *Journal of small animal practice* 34(1): 26-30

Muthusamy S, Rozbruch SR and Fragomen AT. 2016. The use of blocking screws with internal lengthening nail and reverse rule of thumb for blocking screws in limb lengthening and deformity correction surgery:*Strategies in trauma and limb construction* 11(3):199-205

Newton CD and Nunamaker DM. 1985. Methods of Internal Fixation. In: *Textbook of Small Animal Orthopaedics* (CD Newton and DM Nunamaker, Eds), International Veterinary Information Service, Ithaca, New York, USA

Raghunath M and Singh SS. 2008. Intramedullary interlocking nailing for management of long bone diaphyseal fractures in dogs: a study of 17 clinical cases. *Indian Journal of Veterinary Surgery* 29(2): 106-09

Raghunath M, Bishnoi AK, Singh SS, Singh M, Sharma A and Atri K. 2012. Management of segmental fractures of tibia and femur by static intramedullary interlocking nailing in twelve dogs. *International Journal of Applied Research in Veterinary Medicine* 10(3): 264-72

Raghunath M. 2002. Studies on intramedullary interlocking nailing and dynamic compression plating on long bone fracture fixation in dogs. PhD Thesis, Department of Veterinary Surgery and Radiology, Punjab Agricultural University, Ludhiana, India

Rommens M, HessmannH. 2015. History of intramedullary nailing. In: *Intramedullary nailing: A comprehensive guide*. ISBN-13: 978-1447166115P 3-12

Roush JK, McLaughlin R M. 1999. Using interlocking nail fixation to repair fractures in small animals: *Agris.* 94(1): 46-52

Saleh KJ, Thongtrangan I, Schwarz EM. 2004. Osteolysis: medical and surgical approaches. *Clin Orthop Relat Res* 427:138–147.

Simon SMR, Ganesh S, Ayyappan, Rao GD, Kumar SR, Kundave VR and Das BC. 2010. Incidences of pelvic limb fractures in dogs: A survey of 478 cases. *Veterinary World* 3(3): 120-121

Singh D, Singh R, Chandrapuria VP and Vaish R. (2017). Occurrence pattern of different types of fracture in bovine, caprine and canine. *Journal of Animal Research* 7(4): 745-749

Singh M, Yadav RK, Raghunath M and Singh SS. 2007. Repair of bilateral femur fractures with static intramedullary interlocking nailing in three dogs: a clinical report. *Indian Journal of Veterinary Surgery* 28(1): 48-49

Slatter DH. 2003. Text book of Small Animal Surgery. Saunders an imprint of Elsevier science, the Curtis centre, Independence square West, Philadelphia PA 19106, ISBN 0-7216-8607-9. P 1807-1809

Sran TK, Singh SS, Mohindroo J and Saini NS. 2016. Frequency of long bone fractures in dogs: A retrospective study. *Indian Journal of Veterinary Surgery* 37(1): 1-5

Yadav RK. 2005. Studies on the evaluation of different types of interlocking screws in static intramedullary interlocking nailing for canine long bone fracture fixation. M.V.Sc thesis. Department of Veterinary Surgery and Radiology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana

**Brief Bio-data of the Student**

| | | |
|---|---|---|
| **Name** | : | Sakshi |
| **Father's Name** | : | Sh. Ravinder Singh |
| **Mother's Name** | : | Smt. Suman |
| **Date of Birth** | : | 27/02/1994 |
| **Permanent Address** | : | Vill Gartheri Brahman, P.O Jhaniyari devi, Teh and district Hamirpur (HP) 177001 |

**Academic Qualifications**:

| Qualification | Month, Year | School | Board/ University | Marks (%) | Division |
|---|---|---|---|---|---|
| 10th | March 2009 | Govt. girls senior secondary school Hamirpur | HP board Dharmshala | 87.14 % | 1st |
| 12th | March 2011 | Gurukul public senior secondary school Hamirpur | HP board Dharmshala | 88.2% | 1st |
| B.V.Sc.&A. H. | July 2017 | - | CSKHPKVH PAU | 76.09 | 1st |