CLINICAL EVALUATION OF ONE COMPARED TO MULTIPLE DISTAL FIXATION SCREWS IN STATIC INTRAMEDULLARY INTERLOCKING NAILING FOR MANAGEMENT OF CANINE LONG BONE FRACTURES

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF VETERINARY SCIENCE
in
VETERINARY SURGERY AND RADIOLOGY
(Minor Subject : Vetərinary Anatomy and Histology)

By

Manpreet Singh
(L-2002-V-47-M)

Department of Veterinary Surgery and Radiology
College of Veterinary Science
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004

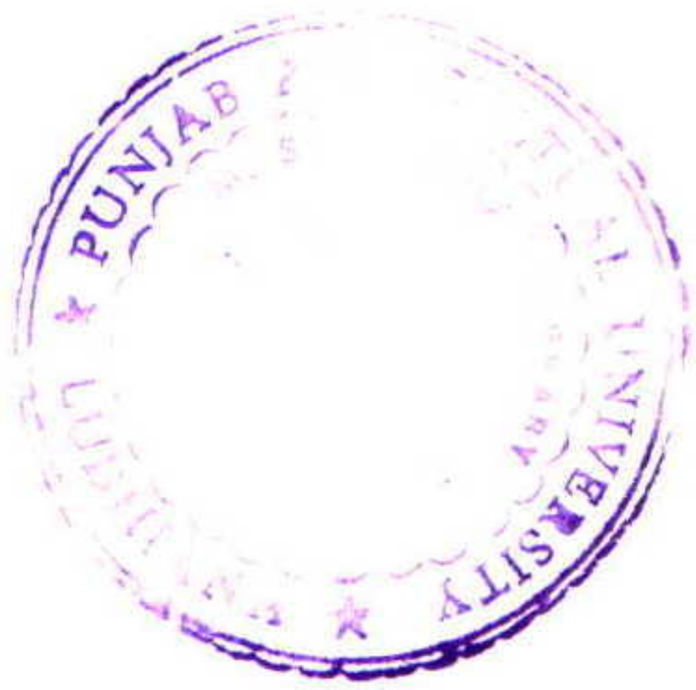
2004

CLINICAL EVALUATION OF ONE COMPARED TO MULTIPLE DISTAL FIXATION SCREWS IN STATIC INTRAMEDULLARY INTERLOCKING NAILING FOR MANAGEMENT OF CANINE LONG BONE FRACTURES

Thesis

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements
for the degree of

MASTER OF VETERINARY SCIENCE
in
VETERINARY SURGERY AND RADIOLOGY
(Minor Subject : Vetərinary Anatomy and Histology)



By

Manpreet Singh
(L-2002-V-47-M)

Department of Veterinary Surgery and Radiology
College of Veterinary Science
PUNJAB AGRICULTURAL UNIVERSITY
LUDHIANA - 141 004
2004

Dedicated

To my

Revered

Grand Parents...

CERTIFICATE I

This is to certify that the thesis entitled, "**Clinical evaluation of one compared to multiple distal fixation screws in static intramedullary interlocking nailing for management of canine long bone fractures**" submitted for the degree of **Master of Veterinary Science**, in the subject of **Veterinary Surgery and Radiology** (Minor subject: **Veterinary Anatomy and Histology**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Manpreet Singh (L-2002-V-47-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

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

Major Advisor
(Dr. S. S. Singh)
Professor and Head
Deptt. of Vety. Surgery and Radiology
Punjab Agricultural University
Ludhiana -141 004, India.

CERTIFICATE II

This is to certify that the thesis entitled, "**Clinical evaluation of one compared to multiple distal fixation screws in static intramedullary interlocking nailing for management of canine long bone fractures**" submitted by **Manpreet Singh (L-2002-V-47-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for degree of **Master of Veterinary Science**, in the subject of **Veterinary Surgery and Radiology** (Minor subject: **Veterinary Anatomy and Histology**) has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

14.6.04

Major Advisor
(Dr. S.S Singh)

Sureshwar Nath Sharma 14/6/04

External Examiner

Dr. S.N. Sharma
Ex-Professor & Head
Deptt. Vety. Surgery & Radiology
P.A.U., Ludhiana-141004.

14.6.04

Head of the Department
(Dr. S. S. Singh)

21/6

Dean, Post-Graduate Studies
(Dr. Darshan Singh)

ACKNOWLEDGEMENTS

First of all, I bend down with reverence and high regards to the loving memory of my Grand Dad Late "S. Surjan Singh" whose inspirations and set of guidelines have always acted as a source of enormous power for me to endeavor to know more and work for the cause of improving my knowledge.

With deep privilege and enormous respect I express my deep sense of thankfulness and utmost gratitude to my Major Advisor Dr. S.S Singh, Professor and Head, Department of Veterinary Surgery and Radiology for his invaluable guidance and suggestions, particular and constructive criticism, ever willing assistance and regular back-up in the whole project. It is to be sure a matter of great pride for me that I received his guidance for this project and my master's degree.

I owe my thankfulness to the dynamic members of my Advisory Committee, Dr M. Raghunath, Assistant Professor, Department of Veterinary Surgery and Radiology, Dr K. S. Roy, Professor and Head, Department of Veterinary Anatomy and Histology and Dr J. Mohindroo, Assistant Professor, Department of Veterinary Surgery and Radiology (Dean, PGS Nominee) for their invaluable suggestions and supervision.

I would like to convey here my deep regards to Dr. M. Raghunath, for his wise and very useful guidance, continuous and indefatigable interest, and encouragement throughout the course of my studies and this project. His unrelenting and firm determination, along with his commitment for the profession would always inspire me to work hard with similar willpower and pledge.

I express my earnest thanks to the faculty members of my department Drs. N.S Saini, Arun Anand, Shashi Kant, Mandeep Chaudhary, Ashwani Kumar, Navdeep Singh, Jagjeet Cheema and Amandeep Toor for rendering their co-operative attitude and righteous support. The friendly attitude and team work approach of all the faculty members is only one of its kinds which offered a wonderful environment to work in.

Whole hearted thanks are to my colleagues-cum-friends, Drs Inderjeet, Preet Mohinder, Kuljit, Gurbinder, Vikas, Garry, Pramod, Saggu, Madhu & Yadav for their co-operation throughout my research work. But special thanks are due to my brother

Dr. Jaspreet for his continuous backing, inspiration, honest support, rendering his assistance wherever and whenever need arose. Without his involvement the things would have happened but with great intricacy.

I reserve my thanks to my family members for their continuous inspirations and blessings which always filled me with strength to face the troubles during my research work. Special thanks to my friends Dhillon, Navjeet, Saini, Manpreet, Bikram and Amrit for their support and encouragement.

I affectionately acknowledge the love, care, moral support and encouragement received from Jhansi.

The assistance of laboratory and other staff especially Mrs Allykutty Jacob, Mr. Subash Chander & Mr. Manmohan is highly valued.

The professional assistance of Puneet and Maan (Super Natural Designers) in writing thesis is highly acknowledgeable.

Thanks to my uncle Raju for providing me his camera for photography.

The financial assistance in the form of University Merit Scholarship from Punjab Agricultural University during the study period is duly acknowledged.

Last but not the least; I acknowledge my gratefulness to almighty, whose blessings and support proved a real windfall for me during this segment of life. I duly acknowledge my sincere thanks to all those who love me and care for me.

All may not be cited, but none is forgotten.

Place : LUDHIANA
Date : 1-6-04

Manpreet Singh.
(Manpreet Singh)

Title of the Thesis	:	Clinical evaluation of one compared to multiple distal fixation screws in static intramedullary interlocking nailing for management of canine long bone fractures.
Name of the student and Admission No.	:	Manpreet Singh (L-2002-V-47-M)
Major Subject	:	Veterinary Surgery and Radiology
Minor Subject	:	Veterinary Anatomy and Histology
Name and Designation of Major Advisor	:	Dr. S. S Singh Professor and Head Department of Veterinary Surgery & Radiology
Degree to be Awarded	:	M.V.Sc.
Year of award of Degree	:	2004
Total Pages in Thesis	:	108 + (Vita)
Name of University	:	Punjab Agricultural University, Ludhiana-141004, India.

ABSTRACT

The present study was conducted on 19 clinical cases with 21 long bone fractures to evaluate and compare the clinical efficacy of the static intramedullary IL nailing with respect to placement of transcortical screws in the distal fragment of the fractured bone. The study was divided into two groups. Static intramedullary IL nailing was carried out. In group I (n=7) one distal transcortical screw was placed and in group II (n= 14) more than one distal transcortical screws were placed. Fracture reduction and intraoperative stability was comparable for both the groups. The time for fracture healing was also comparable in both the groups. The dogs were able to walk without any difficulty by 10th post operative day. In both the groups the clinical outcome was found to be as high as 85 % in group I and 83 % in group II. No case of rotational deformity, limb shortening was noted in both the groups. The implant related complications included misdirected screw; screw bending, screw breakage and screw back out. These complications were seen mostly in distal screws of 6 mm nail, when the distal screw was close to fracture line in a distal fracture. No case of nail breakage and nail bending was reported. Static intramedullary IL nailing proved to be an effective means of internal fixation modality with a high rate of clinical outcome resulting in quick rehabilitation of affected animals. The larger diameter nail with more number of transcortical screws in the distal fragment in a distal fracture provides better implant reliability than a smaller diameter nail with single transcortical screw. However, the screw related complications do not have any profound effect on the clinical outcome of this fracture fixation modality.

Key words: Dogs, Fractures, Static intramedullary IL nailing, Screws, Healing, Complications.

SSSingh

Signature of the Major Advisor

Manpreet Singh

Signature of the Student

LIST OF ABBREVIATIONS

µg	:	Microgram
@	:	At the rate of
AO	:	Arbeitsgemeinsehaft Fur Osteosynthese Frasen
ASIF	:	Association for the study of internal fixation
b.i.d	:	Twice a day
cm	:	Centimeter
D	:	Dog
DLC	:	Differential leukocyte count
FCW	:	Full cerclage wire
Fig	:	Figure
G	:	Group
g	:	Gram
Hb	:	Haemoglobin
IL	:	Inter locking
IM	:	Intramuscular
Inj	:	Injection
IV	:	Intravenous
kg	:	Kilogram
L	:	Liter
M	:	Month
mL	:	Millilitre
mm	:	Millimeter
no.	:	Number
PO	:	Per Os
RBC	:	Red blood cell
SC	:	Subcutaneous
t.i.d	:	Thrice a day
Tab	:	Tablet
TLC	:	Total leukocyte count
WBC	:	White blood cell

LIST OF TABLES

CONTENTS

Chapter I

INTRODUCTION

The incidence of musculoskeletal injuries particularly fractures is on the rise in pet animals due to rapid urbanization and increased vehicular traffic. Fracture is defined as a break in the continuity of bone which may be caused either by a direct high energy trauma or by indirect trauma of varying intensity. Males are often more affected than the females and the incidence of fractures is higher in hind limbs (60%) than in the fore limbs (40%). Among various bones the fracture of femur is highest in report being (36.6%) of the total cases followed by tibia (23.3%). The type of fracture varied from transverse (40%) to overriding in (30.5%), oblique in (23.3%) and distracted in (1%) of the total cases (Singh *et al* 1999).

The ideal objective of the fracture treatment is to provide a completely rehabilitated patient as quickly as possible. Successful treatment plan comprises a perfectly aligned bone of full length that has solidly united joints that are freely movable to their fullest range of motion with intact musculature and innervations and the integument surrounding the site that is completely normal. Fracture repair in small animals is often challenging due to extensive expertise needed to gain success in treating such patients, choosing the right implant for fracture fixation from the vast array of fracture repair appliances available and providing the high standard of care needed for regaining functional ability (Roush 1998).

For successful fracture repair thorough understanding of the forces acting on a bone during fracture healing is a must and the repair must counteract almost all the forces to allow optimal healing process to take place (Roush and McLaughlin 1998).

A plethora of techniques are available for fracture fixation, each technique having its own merits and demerits. Simple intramedullary pinning is relatively simpler and inexpensive technique for management of fractures requiring comparatively lesser expertise which makes it highly acceptable and widely practiced technique in small animal orthopedic practice for management of long bone fractures. However, the technique offers lesser stability, resulting in more chances of complications attributed mainly to rotational instability of the fracture fragments. Fracture fixation using various types of bone plates and screws is widely practiced and is also effective to stabilize the unstable fracture fragments. Bone plates can resist compression, bending, and torsion forces or their physiological combinations applied to the bone during the initial phase of healing. In spite of various advantages, the fixation of the plate on bone requires excessive surgical exposure and excessive periosteal stripping which leads to slowing down of healing process or leads to non-union. The stiffness of the plate may also induce a "stress protection" effect as the bone under plate is essentially unloaded (Bernarde *et al* 2001).

Intramedullary IL nailing, a modification of K-nail, is the latest surgical technique among the internal fixation procedures used in long bone fracture

repair. Due to rare availability of intraoperative fluoroscopic guidance in veterinary practice, the placement of IL nails requires, as for the plates, an open approach to the bones. Development of IL nailing implant system using an external aiming device has allowed its use in veterinary practice and now IL nailing procedure has become an effective means of fracture fixation in long bones fracture management especially femur, tibia and humerus. The nail is attached to the insertion device and inserted into the marrow cavity of the fractured bone, and, then fixed by screws at the distal and proximal ends with a jig or aiming device which is also attached to the insertion device.

The substantial benefits documented with the use of IL nail over the use of plates for similar fractures include reduced infection rates, reduced blood loss, reduced surgical time and shortened hospitalization. The IL nail overcomes many of the limitations associated with the IM pins including collapse of the comminuted fractures, rotational instability and pin migration. The function of IL nail is to stabilize the fracture fragments allowing the load transfer across the fracture site while maintaining anatomical alignment of the bone. The inherent mechanical strength of IL nails and bone screws that pass through the bone and nail help to control rotational and shear forces.

In India, indigenously designed and manufactured IL nailing implant system has been introduced and used successfully for management of canine long bone fractures (Raghunath and Singh 2002). Although IL nail provides resistance against axial forces, no study has been performed to assess axial cyclic forces on

the interlocking screws to be locked transcortically distally, as they influence the mechanical stability of the IL nail as well as the locking screws. More information is still needed concerning the study of fracture fixation using static IL nail and the arrangements of screws in the distal fragment of the fractured bone. The present work was thus planned with the following objective:

- To compare the application of one versus multiple interlocking screws in the distal bone fragment in static intramedullary interlocking nailing in diaphyseal long bone fracture fixation.

Chapter II

REVIEW OF LITERATURE

The available literature is reviewed under two headings:

1. Fractures, fixation devices and associated complications.
2. Intramedullary IL nailing

Fractures, fixation devices and associated complications

Grono (1964) reviewed the treatment of 222 canine fractures during the years 1960-1962. He concluded that out of these, (32 %) of cases were of femur fractures, of which, (75%) involved diaphysis of the femur. He also compared his results with those of five other centers and found that in each study femur was most commonly affected bone. He concluded that the intramedullary pinning was the method of choice for fracture fixation of the femoral shaft. Fixation with the Thomas splint was not useful for the femur fractures.

Maala and Celo (1975) studied the records of fractures in dogs over a period of 8 years and found that fractures of femur had the highest incidence as (52.1 %). For the other bones, incidence was as radius (6.1 %), tibia (3.6%), ulna (3.6%), tibia and fibula (2.4%) and fibula (1.7%), metacarpals and vertebrae (1.2 %) and ribs (0.6%). Of the 85 femoral fractures studied, 68 (85%) were complete with some degree of comminution. The cause of trauma was mostly traffic

accidents. The incidence of fractures was higher in male dogs (69.3 %) than in female dogs (30.6%).

Presnell (1978) compared the cost involved and surgical time associated with the intramedullary pin and bone plating techniques. He opined that there is a sizable difference between the costs of a large plate versus a large pin, the cost of platting being much more than a pin. The surgical time is more in most cases of plate application than for the insertion of the intramedullary pin. The soft tissue exposure is much more for the plate fixation. Also surgical removal of pins requires very little time and surgical preparation, compared with the removal of plates and screws. However, plates give very rigid fixation as compared to simple intramedullary pins.

Phillips (1979) surveyed 284 canine and 298 feline fractures. Approximately (80%) of fractures occurred in animals less than 3 years of age. Males were most commonly involved than the females. Road accidents were the main cause of fractures, followed by fall from height and crush injury. In dogs, femur was involved in (74.8%) of the total cases.

Hunt *et al* (1980) described the complication of the diaphyseal fractures treated surgically and non surgically, with record of 100 dogs and stated that major cause of failure and subsequent delayed union and non union was relatively instability resulting from the inadequate immobilization of the fracture fragments. Instability associated with the intramedullary pinning was either due to use of pin

of insufficient diameter or not embedding the pin well in the distal fragment predisposing its upward migration.

Parker and Bloomberg (1984) developed a modified intramedullary pin technique for the surgical repair of the distal femoral physeal fractures in dogs and cats and concluded that this technique provided stability at the fracture site and allowed early range of motion. The fixation was compared with that achieved with a multiple pin technique and the technique was concluded to be a better than the multiple pin technique.

Wong (1984) surveyed the fractures incidence in 61 dogs and 26 cats presented during 1980-1983 at the veterinary hospital and concluded that more than 80 % of fractures occurred in animals less than two years of age. Male animals were more frequently involved. In dogs the femur, tibia, pelvis, radius and ulna were most commonly affected in order of occurrence.

Nunamaker (1985a) described the method of Robert John bandaging and opined that it is useful for the traumatized extremities with a great deal of swelling and edema. The principle involved in fixation was that of large bulky dressing wrapped around the limb evenly and tightly to the extremity, providing extreme comfort and immobility to the injured site.

Nunamaker (1985b) opined that single intramedullary pin did not provide sufficient stability at the fracture site. Instability of the fracture, especially of the femur, allowed the formation of the rotational deformity, with an external rotation

of the proximal fragment as a result of the pull of the illiopsoas muscle. Dog presented an abnormal gait with the affected paw rotated internally.

Tamas *et al* (1985) analyzed the age and sex distribution as well as seasonal incidence for 367 dogs and cats with either forelimb or hind limb fractures following motor vehicle accidents and found that (54%) of the patients with limb fractures were one year of age or younger. The highest incidence of the limb fracture occurred in intact male dogs (55%) followed by intact females (29%), spayed females (13%) and castrated males (3%) respectively. Most of the fractures occurred in the spring season (34%) followed by winter (29%) months.

Boone *et al* (1986) evaluated a total of 43 fractures of distal tibia in dogs and cats and the time of bony union after using different methods of stabilization. Fractures of metaphysis were (9.3%), physis (30.9%), epiphysis (2.3%) and malleoli (58.2%). The fractures were stabilized with open reduction and internal fixation with combination of techniques including Kirschener wire, orthopedic wire and bone screws and an average bone healing time of 6 weeks was found in almost all the cases.

Knecht *et al* (1987) advocated the use of Robert John bandage as a single dressing for the temporary immobilization of the limbs. The bandaging provided even pressure, there by preventing or reducing edema and secondary complication that frequently arise due to injury to soft tissue by broken bones.

Axelson *et al* (1988) described a method of internal fixation using a rod shaped biodegradable implant made of self re-inforced polyglycolic acid (PGA). The fractures healed clinically and radiologically in 6 weeks without complication and lameness. They opined that biodegradable fixation devices would be a key tool in treatments of fractures in small animal veterinary surgery in near future.

Church and Schrader (1990) used the flexible intramedullary rods made up of high density polysulfone to repair the mid shaft diaphyseal femoral fractures in 8 dogs. The failure of this technique was attributed to the fact that the multiple autoclaving of the thermoplastic implants caused its embrittlement and subsequent breakage.

Dallman *et al* (1990) compared the rotational strength of double pinning technique in repair of the transverse fractures in femurs of dogs and found that multiple pinning techniques was 1.8-3 times as effective in resisting rotational forces as compared to other pinning techniques.

Patil *et al* (1991) surveyed a total of 471 clinical cases of fractures recorded over a period of 10 years. The findings in the study concluded a higher incidence (35%) of femoral fractures. Most of the fractures involved the shaft of the bone and were either comminuted, oblique or transverse in nature. Incidence of fractures in males was more than in females.

Miller *et al* (1998) described AO/ASIF fracture classification system of long bone fracture using an alpha numeric code to identify fracture location and

morphology. The system was found to be easily adaptable for cats and dogs and provided a more complete description of the fracture morphology than was possible with other fracture classification systems. In AO/ASIF fracture classification system, the first digit code identifies the bone (1-Humerus, 2-Radius-Ulna, 3- Femur, 4- Tibia-Fibula). The second digit code identifies the location of the fracture in the bone (1-Proximal, 2-Diaphyseal, 3-Metaphyseal). The fracture morphology was described using a letter A, B, C as A- simple, B-Wedge fractures, and C- complex fractures.

Glennon *et al* (1994) conducted a study to determine the long term effect of bone plate application for the fixation of the radial fractures in dogs and concluded that there was no significant correlation between the change in the radial cortical density and the duration of the bone plate application suggesting that a steady state between bone loss and bone production occurs after a long term plate fixation of the fractured canine radius. They have reported that (87%) of the dogs with plate applied to the radius more than one year had normal limb usage when standing, walking and running.

Balagopalan *et al* (1995) reviewed 208 cases of fractures in dogs. They found that fractures of hind limbs (65.9%) were more than those of forelimbs (21.2%). Incidence of femur fractures was highest (35.9%) and most of the animals were under one year of age (78.4%). Fractures were seen mostly in middle and distal third. In (55.5 %) of the cases left femur was involved.

Branden *et al* (1995) described the characteristics features of 1000 femur fractures in dogs and cats. Fracture occurrence was evenly distributed throughout the year with July having maximum (11%) occurrence. Maximum (62%) of the total patients were male. Most of the fractures were observed in animals less than 2 years of age. Shaft was the most common, (56%) fracture site. Open reduction was performed in most (89%) of the cases. Intramedullary pinning was used in only (29%) of cases as a primary means of fixation.

Ramon *et al* (1996) investigated the effect of long term application of bone plates on the bone tissues by using arteriography and densitometry determinations. The bone tissues were obtained from the bones treated with compression or fixation plating and it was concluded that bones treated with the compression plates became more demineralized with delayed remodeling. The porosity of the bone tissue surrounding and underneath the compression plate increased with time. Arteriographic studies also showed clearly scarcity of blood vessels in areas where compression plates produced more damage to bone tissue and therefore resulted in delay in consolidation due to local osteoporosis.

Zaal and Hazwinkel (1996) classified 202 tibial fractures in dogs and cats according to the system of Unger classification over a period of 6 years and found that most (73%) of these fractures were diaphyseal with oblique type being most frequent (24%). Proximal tibial fractures were usually extra articular and most (87%) of this involved avulsion of the tibial tubercle. Malleolar fractures accounted for (57%) of the distal fractures. The author concluded that Unger

system of classification to be useful for inventory and documentation, but because of lack of data for the physeal fracture, the degree of injury to surrounding tissues, and the influence of difference between the surgeons, it is least useful to determine the therapy.

Wang *et al* (1998) conducted a study to investigate that whether bone fracture properties change with species. They compared the density and volume fractions of the minerals and organic phases as well as studied bone microstructures. There were significant difference for the bone fractures properties between human and other three animal species namely, dog, sheep and rabbit which were reflected in bone microstructure and compositional properties.

Aithal and Singh (1999) studied the pattern of bone fractures in dogs and concluded that road traffic was the main cause of fractures (46.68%) followed by fall from height (39.11%). Most of the fractures were seen in animals less than 1 year of age. Male dogs were affected more than the females. Majority of fractures involved hind quarters (64.5%). Left hind limbs were commonly affected (62.2%), than right hind limb (37.88%). Among different types of fractures caused by road accidents majority (49.7%) were oblique or spiral.

McLaughlin and Roush (1999) opined that plates and screws effectively stabilized long bone fractures in small animals. Besides providing rigid fixation, they controlled all the forces acting on the fracture site and allowed early return of the limb function.

Radcliffe *et al* (2001) conducted an *in vitro* biomechanical comparison of interlocking nail constructs and double plating for the diaphyseal femur fracture fixation in immature horses and concluded that two DCP femoral construct provided superior strength and stiffness as compared to interlocking nail and single DCP constructs under healing and torsion. So, double plating of the diaphyseal comminuted femoral fracture in immature horses would be best method for the repair as it provided the greatest strength and stiffness in bending and torsion.

Intramedullary interlocking nailing

Sedel *et al* (1979) compared the mechanical properties of the callus in fractures treated by nailing or plating in their study conducted on sheep. The mechanical properties of the callus were assessed by resistance to rupture, tangential strain measurement, the energy required to rupture, module of elasticity and moment of inertia and concluded that callus was much superior quantitatively and qualitatively after nailing which were related to its degree of mineralization.

Rand *et al* (1981) compared the effects of compression plating and open IL nailing after reaming, on the vascular supply to a standard fracture site, the rate of bone union and biomechanical quality of the bone after union in dogs. Bone blood flow was found to reach at the higher levels and remained elevated longer in fractures that were treated with IL nails than in those with the plate. Nail fixed fractures healed with periosteal callus, whereas plate fixed fractures healed by

endosteal callus. The fractures fixed with the IL nail gained mechanical strength more slowly than in the plate fixed group.

Colchero *et al* (1983) described a new type of IL nail for femur and tibia in which the nail was locked by the provision of holes into which the screws could be locked by driving screws transversally. Out of 146 clinical cases which were operated by open reduction of the fracture, only two cases of non union were noted. The authors reported the method to be superior to plating.

Kempf *et al* (1985) conducted their study on the closed locked intramedullary nailing and its application to comminuted fractures of the femur and concluded that technique provided greater stability even in the severely comminuted, oblique and spiral fractures as well as to the fractures that were complicated by loss of bone and fractures in the proximal and distal ends of the femoral shafts. They also concluded the method to be free from the incidence of infections, malunion and offered early mobilization of the patient. They recommended the conversion of static locking to dynamic one by removal of screws on one side of the fracture once adequate callus was formed and when compression was desirable at fracture site.

Kyle (1985) conducted studies on the biomechanics of intramedullary fracture fixation and concluded that intramedullary IL nail allowed transmission of the compressive load and were not detriment to union. The strength of an

osteosynthesis with an intramedullary rod depended on the geometry of the rod and the geometry of the fracture complex as well.

Bone and Johnson (1986) conducted a study on 112 fractures of tibia in human patients by manipulative reduction, reaming of the medullary canal and stabilization of the fractured bones with an intramedullary nail and concluded that shortening in comminuted fracture or rotational instability in proximal and distal fracture could be prevented by use of locking nail.

Medoff (1986) in a study concluded that by determining the alignment axis of a distal screw hole with image intensifier would overcome the problem associated with the distal screw hole locking in locked IL nailing for femur shaft fractures. The free hand technique described by him used the camera of the C-arm with limited adjustment as an alignment guide to overcome the several potential sources of errors in placement of distal screw.

Winquist *et al* (1986) treated a total 520 cases of human femoral fractures using closed intramedullary nailing technique and concluded that the technique offered a high union rate (99.1%) with an average hospital time of 13.3 days and time before walking with crutches on an average was 3.2 days after surgery. They opined that introduction of closed IL nails allowed maintaining the length and preventing the rotation in comminuted fractures, and used mostly for the closed reduction helped in rapid mobilization of patients.

Bucholz *et al* (1987) studied the clinical and biomechanical factors predisposing to a fatigue fracture of IL nail in human patients treated for a distal femoral fracture and concluded that in all the patients fracture line was less than five centimeters from the more proximal of the two distal holes. They opined that the risk of fatigue failure of nail might be minimized by using nails that have a larger diameter and by avoiding early weight bearing.

Reikeras (1987) conducted a study on the cardiovascular reactions in relation to the reaming of the medullary cavity of femoral bones in dogs and found that the intramedullary reaming resulted in marked reduction in systemic and pulmonary arterial blood pressure. Total peripheral resistance was reduced; however cardiac output remained same or maintained. The haemodynamic changes were transient.

Brumback *et al* (1988) reported that femoral shafts treated with the statically locked IL nails healed in most (98%) of cases without the need of dynamization. The static locking is sufficient unless the dynamization is really warranted. They also concluded that static intramedullary IL nail in femoral shaft fracture did not appreciably inhibit the process of healing and that routine conversion of dynamic IL fixation, although occasionally necessary but need not to be performed every time.

Bostman *et al* (1989) reported the incidence of local complications after intramedullary nailing and plating of the femoral shaft fractures in a series of 378

human patients with 381 acute femoral fractures. The complication rate was higher (24%) in plating and lower (4.7%) with IL nailing and the reoperation rate was (25%) and (6%) in plating and IL nailing, respectively. They opined that the degree of comminution of fracture showed clear correlation with the complication rate, especially with plate fixation.

Georgiadis *et al* (1990) conducted experimental study in dogs on effects of dynamization after IL tibial nailing in canine model. Sixteen canine tibiae with unstable osteotomies were treated with reamed static interlocking nails. At 8 weeks half were dynamized. At 20 weeks the tibiae were harvested and studied radiographically, biomechanically and histologically. Complete radiographic bone union was evident in 13 of 16 dogs with residual radiolucent lines in two tibiae in static group and one in dynamic group. Biomechanically dynamization improved stiffness at fracture site. Histological patterns were similar in two groups, but there were trends towards a denser trabecullar callus pattern in dynamized group. It was concluded that although dynamization may have a beneficial effect on the quality of early bone healing static IL did not limit the bony union.

Johnson and Tencer (1990) conducted a biomechanical study to assess the function and performance of intramedullary nails for the femoral fractures and concluded that the distal locking bolts increased the torsional rigidity and maximum axial load capacity of the construct and reduced the potential of shortening and the residual deformation upon release of the torsional load.

Klein *et al* (1990) investigated the effect of reaming prior to nail insertion upon the cortical circulation in the canine tibia. They concluded that the nail insertion without reaming provided clear advantages for the bones blood supply while reaming disturbed the perfusion in the two thirds of the cortical area and regionally extended through the entire thickness of the cortex however the disturbance without reaming was limited to the inner layer of the cortex and involved only one third of the cortical cross section.

Alho *et al* (1991) performed locked intramedullary nailing of 123 femoral shaft fractures in humans and suggested that double distal locking was necessary in distal fractures and in the osteoporotic or pathological fractures in which the screws had a tendency to lose the hold.

Wiss *et al* (1991) treated low-velocity gunshot injuries leading to comminuted fractures in man with IL nailing. Stable internal fixation was difficult or impossible with use of only plates and screws or with simple intramedullary nails. Only IL nail could prevent the rotational stress and shortening of limb in such fractures.

Brumback *et al* (1992) investigated the long term effects of the static IL nailing fixation of femoral shaft fractures to determine the clinical importance of any stress riser or stress shielding properties of the nail. These properties, if relevant would have been manifested by refracture of femur, either through a hole used for a locking screw due to stress riser or through original site of fracture due

to stress shielding after extraction of the implant. They observed that in both the groups, in which the implant was retained after healing in one group and removed after an average period of fourteen months in another group, there was no incidence of refracture of femur or breakage of the locking screws or the nail. They concluded that problems of stress shielding and stress risers were not clinically evident and that healing of fracture evident by radiological evidence must be assured before implant removal.

Uta (1992) developed a new intramedullary nail of J-type and tested *in vitro* with femur models as well as *in vivo* using canine models and the strength of this nail was also evaluated which was found to be comparable to standard nails available as to bending, torsional and compression stiffness as well as to the durability against the repeated compressive forces.

Benirschke *et al* (1993) encountered 3 cases in which the comminution increased at the fracture site when nail was being introduced and one case of bent nail. They concluded that nailing was an effective method for closed fracture fixation however not free from local and technical errors that could be removed with technical expertise.

Durall *et al* (1993) investigated return of the function and callus healing in group of 10 dogs after ostoetomies of femur after treating with IL pins. The results revealed full return of limb function by 4-16 days and consolidation of callus between 8-10 weeks.

Hajek *et al* (1993) conducted a clinical and biomechanical analysis on the torsional and compressive biomechanical characteristics of a system for intramedullary fixation with a slotted locking nail with either one or two distal screws in cadaver femur. No significant difference was found in the torsional rigidity or axial load to failure when one as opposed to two distal screws was used. The study concluded that one distal screw provided adequate distal fixation of the fracture of the femoral shaft treated with IL nailing.

Tanna (1993) reported a method for locked tibial nailing for circumstances where image intensifiers were not available, using hollow tubular nails with no slits and anterio-posterior holes for locking screws. When the nail was fully introduced another nail was placed over the skin exactly parallel to the first one to act as a jig and Kirschener wires were passed through the holes in it and impressions on the anterior cortex of tibia were marked. The exact point of entry in relation to wire was studied and then the screws were inserted and tightened. The technique expanded the use of locking nails successfully without the use of sophisticated devices like image intensifiers, flexible reamers and jigs.

Wu and Shih (1993) in a retrospective study done on the effect of dynamization of static IL nail on the fracture healing found that static IL nailing without dynamization could still produce a high union rate and if there was a sparse callus formation during healing process; indicating a low rate of osteogenesis, dynamization resulted in fracture union only in half of the cases. The author opined the use of cancellous bone grafting to improve the union rate.

Durall *et al* (1994) treated 7 cases of the humeral fractures in dogs with IL nail. 6 cases were statically and one was dynamically locked. Healing took place within a period of 16 weeks and return of function was observed within 3 weeks.

McDuffee *et al* (1994) conducted an *in vitro* biomechanical investigation of an IL nail for fixation of diaphyseal tibial fracture in adult horses. The compressive, bending and torsional mechanical properties of the osteotomized adult equine tibiae stabilized with an IL intramedullary nail were compared with those intact tibiae to determine the clinical application and efficacy of the nail for the repair of the tibial fractures in adult horses.

Bohm *et al* (1995) have documented the advantage of solid nails over the hollow nails in terms of bending resistance and yield force. No case of mechanical material failure occurred with the solid nails in animal experiments even in long term experiment follow-ups over nine months.

Duhautois (1995) carried out a case control study on 45 small animals having undergone IL pin fixation to immobilize diaphyseal long bone fractures. 90% of animals showed a satisfactory functional recovery, which had consolidated 3 months after operation. They concluded that as IL pin was very close to the neutral axis of the bone, it does not cause any bone demineralization through stress as in plate fixation.

Eveleigh (1995) reviewed biomechanical studies on the IL nails concluded that in torsion, slotted nails had considerably less rigidity than the nonslotted nails

but in bending, the slot made a little difference in to the nails behavior. They recommended that in unstable fracture, locked intramedullary nail was essential if limb shortening or malunion had to be avoided clinically

Grover and Wiss (1995) conducted a prospective study of fractures of femoral shaft treated with a static intramedullary IL nail and compared one versus two distal screws. The adequate fracture stability without loss of fracture fixation or alignment of fracture fragments was evident in patients after a follow up of over 17 months with one distal screw fixation. The bending of screws in few cases was attributed to early weight bearing and full use of the limb before the formation of adequate stable callus.

Trostle *et al* (1995) in their *in vitro* biomechanical comparison of solid and tubular IL nails in neonatal bovine femur, mechanically tested for the craniocaudal and lateromedial bending, eccentric axial compression and external torsion to evaluate composite rigidity, local gap stiffness and load to failure. They concluded that tubular IL nails were compositely and locally more compliant than solid IL nails of the same diameter and yielded to less bending and torsional loading in osteotomized femur models.

Boyer *et al* (1996) in their study concluded that there was no difference between the rates of union: malreduction and time to radiological union and partial and full weight bearing between the groups of the individuals treated with small diameter versus larger diameter femoral nails. The delayed and non unions

were attributed to the degree of the disruption of the soft tissue envelope. They concluded that small diameter nails can be used in femur without adverse risk of nail breakage.

Dueland *et al* (1996) opined the use of larger size 8 mm IL nail clinically where ever possible as 8.0 mm nail over come the torsional weakness in bone caused by screw hole stress risers. The 8.0 mm diameter interlocking nail with four screws of 3.5 mm or 4.0 mm had adequate bending stiffness, torsional stiffness, and maximum torque for stabilization of diaphyseal femoral fractures in dogs weighing 23 kg or more. 6.0 mm interlocking nails were less stiff than similar 8.0 mm nail in bending and torsion and had less maximum torque. The study also proved that 8.0 mm IL nail with 4 screws of 4.5 mm had similar properties to those of intact femur.

Muir and Johnson (1996) reported successful use of IL nail in a comminuted unstable femur fracture, infected with staphylococcus species with severe pin tract infection. The fracture after treatment with a 6.0 mm IL intramedullary nail and three locking screws healed 8 weeks after surgery. The persistent lameness was resolved when the implant was removed after 17 months. The chronic infection was attributed to the microorganism in biofilm surrounding the implant requiring its removal for resolution.

Endo *et al* (1998) developed an IL intramedullary nail method for the femoral and tibial fracture for the treatment of dogs and cats with different

fracture configurations and concluded that the animals were able to bear weight on the treated leg within three days and the prognosis was excellent. The study revealed that newly devised IL nail system was found to be very effective for 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 opined the removal of the implant when the fracture had healed to avoid stress shielding.

McClure *et al* (1998) conducted an *in vivo* study to evaluate the intramedullary IL nail fixation of the transverse femoral ostoetomies in foals and found that healing was satisfactory in all foals. The author concluded that intramedullary IL nail provided adequate stabilization of the transverse femoral ostoetomies however further investigation is warranted before use for the stabilization of spontaneously occurring fracture configurations.

Brumback *et al* (1999) concluded that the IL nail constructs which had only one distal locking screw had significantly lower fatigue strength than two distal screws constructs. No loss of fixation, such as screw back out or breakage of screw or bending of nail or breakage of nail was reported.

Dueland *et al* (1999) conducted a multicentric clinical study trial for the treatment of diaphyseal long bone fractures in dogs with IL nail and concluded that due to high success rate and relatively low complication rate IL nails could be used very successfully to stabilize the diaphyseal fractures in dogs. Breakage of IL

nails in 9 dogs out of 134 dogs was attributed to fatigue failure because of use of too small an IL nail or because of insertion of IL nail so that a screw hole was positioned at or very close to the fracture site.

Hauschild and Fehr (1999) treated 16 dogs with fractures of long bones using IL nail with the help of drill jig under C-arm control. The study concluded that the intramedullary nailing provided better stability of longitudinal axis of the osteosynthesis and exact reposition of the fragments was not required allowing an atraumatic operation.

Roush and McLaughlin (1999) opined the fact that IL 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.

Wolinsky *et al* (1999) reviewed the outcome of 551 cases of fractures treated with reamed IL nail and stated the procedure resulted in low rates of non union, malunion and hardware failure. High union rate of 99% and low infection rate of (1 %) were observed. They concluded that static IL nailing eliminated the problem of loss of length or reduction in severely comminuted fractures.

Yokoyama *et al* (1999) compared the effect of the immediate and delayed locked intramedullary nailing for open femoral fractures on fracture healing and

found no significant differences in the mean fracture healing times between the two groups.

Lin *et al* (2000) reported the experience with the use of humeral locked nails in treating humeral delayed or non unions. They opined that IL nail had the advantage over plating, causing less tissue trauma and less circulatory impairment. It was the preferred mode of treatment, particularly in the situation in which avascularity was caused by a previous failed osteosynthesis. Locked nails provide antirotational control, prevent migration of nail.

Lorinson *et al* (2000) investigated the results of using IL nails for fixation of long bones fractures in dogs and cats in femur, tibia and humerus. In all the operated dogs and cats, the fractures healed without complications, with excellent limb function. Radiographically fractures healed by 3-4 months. The authors reported that the high rate of success in this study made IL nail system a useful tool in repairing long bone fractures in small animals.

Barnhart (2000) opined the use of IL nail for the fracture repair in small animals and rated it as a valuable tool for treatment of femoral, tibial and humeral fractures especially those which were highly comminuted. He suggested that interlocking nail as much stronger than plate when used in a buttress fashion as the nail is intramedullary and it undergoes much less bending stress than a plate located away from the center of bone (neutral axis). He also concluded that the area moment of inertia for the cylindrical rod is much more than that of a

rectangular plate. In his review of 176 clinical cases, (97 %) fractures had good to excellent results at follow up and overall complication rate of (11 %) was recorded among which distal screw hole miss was the most common.

Duhautois (2001) conducted a monocentric clinical trial to determine and analyze the results on IL nail technique for the stabilization of diaphyseal long bone fractures in dogs and cats. He reported that most (77%) of the cases healed without complication. 26 complications were noted among which 16 animals (14%) did not require any surgical treatment. Three nails were broken and breakage was attributed to an error in the choice of nails diameter and length. The author concluded that with high healing rate, even with the instable fractures, associated with quick recuperation and a low complication rate suggested the efficiency of IL nail in treatment of long bone fractures.

Larin *et al* (2001) documented in their study the outcome of femoral fractures repaired with 4.0mm and 4.7 mm IL nails in cats and concluded that use of IL nails in cats was limited because of small sized diameter of the medullary canal. They successfully treated the 12 femoral fractures in cats of which 11 were severely comminuted and suggested that 4.0 mm nail had a greater application in cats for the repair of simple or comminuted diaphyseal femoral fractures.

Larsson *et al* (2001) studied the effect of early dynamization on tibial bone healing in dogs under experimental condition and compared it with healing under rigid fixation in a time sequence manner. The study concluded that early axial

dynamization appeared to accelerate the callus formation and remodeling and provided higher mechanical stiffness during early stages of bone healing

Lin *et al* (2001) in their biomechanical study concluded that distal locking screws were more vulnerable to mechanical failure. They opined that the stress on the distal screws was substantially affected by the fit of the nail in to the medullary cavity. The stress on the locking screws was found to be function of the distance from the fracture to the locking screws in the distal fragment. The nail-cortical contact decreased the stress on the distal screw.

Sancineto *et al* (2001) reported that breakage of interlocking nail screws was a known complication in tibial fractures treated with IL nailing. This occurred most often in delayed union or non union because of the lack of progressive load transfer from the nail to the healing bone and indicated that nail screws need to be removed to overcome this problem.

Widjaja and Hartung (2001) conducted a biomechanical comparative study of different fixations for the femoral IL nails and concluded that the highest stress concentration occurred at the drill holes of the IL screws. They compared the standard technique with new design of the IL nail and indicated that additional implant increases the stiffness of the bone implant compound and recommended the additional implant in the weak osteoporotic bones.

Langley-Hobbs and Friend (2002) reported the use of 4.7 mm IL nail with four 2.0 mm screws, 20.00 mm in length, two distal and two proximal to treat a

chronic comminuted infected femur fracture in a 18 month old male Bourbon red turkey with success demonstrating complete fracture healing by 9 months. IL nail helped to resist the rotation and collapse of the fracture fragments due to its biomechanical advantageous position, being in the neutral axis of the bone.

Moses *et al* (2002) conducted a multicentric study to assess the suitability of the intramedullary IL nail to stabilize humeral diaphyseal fractures in the dogs and cats. They concluded that if a single transcortical screw applied cranial to tricipital line of humerus, the repair collapsed. They opined the placement of single transcortical screw should be distal or caudal to the tricipital line in order to engage sufficient cortical bone. They concluded IL nailing as well suited to the stabilization of humeral diaphyseal fractures of any configuration in dogs and cats.

Raghunath (2002) in his study over the use of IL nail and dynamic compression plating in long bone fracture fixation in dogs standardized the technique and concluded that static IL nailing provided satisfactory stability and very quick rehabilitation of the limb, resulting in high success rate and less post-operative complications as compared to dynamic compression plating which proved to have poor bending stiffness. He also opined the fact that healing of fracture with the IL nailing was more from periosteal callus and less from endosteal callus where as in plating it was primarily by endosteal callus. The study concluded with a fact that comminuted and rotationally unstable diaphyseal fractures of long bones could be successfully managed with the technique.

Suber *et al* (2002) reported two unusual modes of IL nail failure in dogs and cats. The complication of nail breakout and screw bending were reported and stability of the IL nail within the bone was attributed to its proper placement of the IL nail within the main fracture fragments, maximal medullary canal fitting and adequate nail and screw strength. The screw bending was attributed to the technical errors in nail placement when the proximal distal screw was locked close to the fracture line or was placed in relatively softer metaphyseal bone.

Aper *et al* (2003) studied the effect of bone diameter and eccentric loading on the fatigue life of 2.7 mm diameter cortical screw used for locking a 6.0mm diameter IL nail. A simulated bone model with aluminum tubing and a 6.0 mm diameter nail was used to load screws in a cyclic three point bending. The study concluded that an increase in the diameter of the aluminum tubing resulted in a significant decrease in the number of cycles to lead to failure and within the same diameter the number of cycles of the failure of the eccentrically loaded screws was significantly more than the centrally loaded screws. The study concluded that within a bone, locking screws are subjected to different loading forces and conditions. The fatigue life of locking screw when centrally loaded in the metaphyseal region of bone may be shorter than in the diaphysis and eccentric loading of screw in metaphysis helped to improve its fatigue life.

Duhautois (2003) reported the clinical outcome after use of an IL nail for the stabilization of diaphyseal fractures of dogs and cats. The functional outcome and fracture healing was quantified at 6 weeks and 3 months after surgery with the

radiographic index. The high healing rate associated with good functional outcome and low complication rate supported the use of IL nails for long bone fractures in animals.

Durall *et al* (2003) reported two unusual radiographic findings related to the use of IL nail fixation. The first finding was radiolucency located around the distal tip of the nail observed in the three cases out of 124 clinical cases. The finding was reported to be consistent with wind shield wiper effect seen in association with IL nailing treatment in humans. The complication of screw bending was also observed in the center of the nail in two cases which was attributed to early weight bearing.

Chapter III

MATERIALS AND METHODS

The study was conducted on 19 clinical cases with 21 fractures involving femur, tibia and humerus of dogs registered at the Small Animal Clinics of College of Veterinary Science, Punjab Agricultural University, Ludhiana, during the study period from Nov 2002 to April 2004.

Detailed history was taken from the client in every case. Signalment including age, weight sex and breed were noted (Table 1). A thorough clinical examination was undertaken for all the cases, which included recording of temperature, soft tissue swelling, weight bearing, limb affected and general condition of the animal. Associated injuries following trauma were also recorded in all the cases.

A tentative diagnosis by palpation was made in all cases. Preoperative radiographs in craniocaudal and mediolateral views were taken to assess the location and type of fracture. Blood was collected in EDTA[a] for the haematological analysis which included haemoglobin (Hb), total leucocyte count (TLC), differential leucocyte count (DLC) by standard estimation methods.

---

a-Qualigens Fine Chemicals, Mumbai, Maharashtra

Table 1: Pre operative Signalment of dogs presented for fracture repair (n=19)

S.No.	Age (m)	Sex	Breed	Weight (kg)	Bone	Limb	Type	Initial Presentation	Etiology	Assoc Injury
1.	11	M	Great Dane	40	F	Lt	Simple	3rd Day	Automobile	Nil
2.	42	M	GSD	30	T	Lt	Comp	4th Day	Automobile	Severe bruises
3.	6	M	GSD	25	H	Rt	Simple	2nd day	Automobile	Nil
4.	12	M	GSD	28	F	Rt	Simple	5th day	Automobile	Nil
5.	4	F	Doberman	6.5	F	Lt	Simple	10th day	Automobile	Nil
6.	18	M	Spitz	10	F	Lt	Simple	2nd day	Automobile	Nil
7.	144	M	Spitz	7	T	Lt	Comp	3rd day	Automobile	Nil
8.	3	M	Doberman	8	F	Rt	Simple	1st day	Automobile	Nil
9.	72	M	Gaddi	25	T	Lt	Comp	3rd day	Automobile	Nil
10.	5	M	GSD	20	H	Lt	Simple	1st day	Automobile	Severe bruises epistaxis

Cont... table 1.

S.No.	Age (m)	Sex	Breed	Weight (kg)	Bone	Limb	Type	Initial Presentation	Etiology	Assoc Injury
11.	12	F	GSD	16	F	Bilat	Simple	1st day	Automobile	Severe bruises
12.	6	F	Grey Hound	15	F	Lt	Simple	1st day	Automobile	Severe bruises
13	12	M	GSD	30	F	Lt	Simple	1st day	Automobile	Nil
14.	8	F	Gaddi	30	F	Rt	Simple	6th day	Abuse	Nil
15.	6	M	GSD	20	F	Bilat	Simple	1st day	Automobile	Nil
16.	6	M	Labrador	15	F	Rt	Simple	2nd day	Jump	Nil
17	6	M	Labrador	15	F	Lt	Simple	1st day	Jump	R/U # (Lt) MC #(Rt)
18	12	M	GSD	30	F	Lt	Simple	1st day	Jump	Nil
19	12	M	Great Dane	40	F	Lt	Simple	1st day	Abuse	Nil

m: month, M: male, F: female, GSD: German shepherd, Bilat: bilateral, Lt: left, Rt: right. F: femur, T: tibia, H: humerus, Comp: compound, MC: metacarpal, R/U: radius ulna, #: fracture

Intravenous fluids were given to animals that were dehydrated. The affected limbs were supported with a modified Robert John bandage till the day of surgery. Operations were fixed at the earliest possible date after the diagnosis and treatment plan for the fracture was decided. Clients were advised to bring the animals off feed and water for about 12 hours before surgery. Pre-operative antibiotics and analgesics were given parentally in all the cases. On the basis of radiographic evaluation and visual examination at the time of surgery, AO/ASIF classification of fractures was done. For fracture fixation, the animals were divided into two groups:

Group I: Static intramedullary IL nailing technique for fracture fixation was used with one transcortical screw placed in the distal fragment of the fractured bone.

Group II: Static intramedullary IL nailing technique for fracture fixation was used with more than one transcortical screws placed in the distal fragment of the fractured bone.

The number of transcortical screws placed in proximal fragment varied from one to three in both the groups. The more complicated fractures with severe comminution or segmental fractures with an adequate distal fragment were treated with static intramedullary IL technique with more than one transcortical screws in

the distal fragment. The diameter and length of the nails and length of the screws needed were determined and judged by preoperative radiographs, size and weight of the dog presented for treatment.

Pre Operative Preparation: The dogs were clipped and shaved from hip to hock joint for approach to either femur or tibia and from shoulder joint to the metacarpal region for approach to humerus. The uncooperative dogs were sedated with Xylazine[b] + Ketamine[c] + Atropine sulfate[d] medication parentally for preoperative preparation.

The femur and humerus were approached with dogs in lateral recumbency and affected limb up. However, the tibial fractures were fixed from the medial side of the affected limb, where affected limb was rested on the operation table top.

The surgical area was scrubbed with Aseptic[e] and was painted with Betadine[f] before start of the surgery.

---

b-Inj. Xylocad, Cadila pharmaceuticals, Ahmedabad, Gujrat

c- Inj. Aneket, Neon Lab Ltd, Thane, Maharashtra

d- Inj. Atropine sulphate, BAIF Labs, Ltd. , Wagholi, Maharashtra

e- Aseptic, ICI India Ltd. Chandigarh

f- Wokadine, Wockhardt Vety. Pvt. Ltd., Mumbai, Maharashtra

An intravenous line was maintained and all dogs were administered normal saline solution throughout the operative period and till the recovery from anaesthesia was attained.

Anaesthesia: A common anaesthetic protocol was followed for dogs (n=16) except for 3 dogs which warranted the use of sedative drugs before preoperative preparation due to their uncooperative behavior (Table 2). Irrespective of the fixation technique, the dogs were administered Atropine sulphate @ .02- .04 mg/kg b.w SC 20 min before induction of general anaesthesia. Then the dogs were premedicated with Diazepam[g] @ 0.5mg/kg b.w IV and anaesthesia was induced with Thiopental sodium[h] administered IV to effect. Once the anaesthesia was induced, the dogs were intubated with endotracheal tubes which were then connected to Boyle's apparatus. Anaesthesia was maintained with 0.5- 2 % of Halothane[i] in oxygen by closed circuit method depending upon the body weight of the animal.

---

g-Inj Calmpose, Ranbaxy Lab Ltd, New Delhi-19

h- Inj Intraval Sodium, Rhone- Poulenc India Ltd, Mumbai Maharashtra

i- Fluthane, ICI India Ltd, Chenai, Tamilnadu

Table 2: Combinations of Preanaesthetic and Induction agents

S.No	Combination of drugs	Number
1.	Atropine+ Ketamine+ Xylazine & Thiopental	3
2.	Atropine+ Diazepam & Thiopental	16

Surgical approach: For open reduction of long bones, the approach detailed by Piermattei and Greeley (1979) was followed. For femur, a craniolateral incision was given extending from the level of greater trochanter to the level of the patella. The subcutaneous fascia and fascia lata was incised along the junction of vastus lateralis and biceps femoris muscles. Two muscle bellies were separated by blunt dissection, up to their aponeurosis at the joint level. Caudal retraction of biceps femoris and cranial retraction of vastus lateralis muscle exposed the shaft of the femur. The adductor muscle which inserted on the shaft of the femur was periosteally elevated if necessary.

Tibial shaft was approached over the medial aspect of the affected limb. The subcutaneous fascia was opened in the same line as the skin incision, care was taken to protect the dorsal branch of saphenous vessels and nerve crossing the field at the mid shaft. The bone was exposed by incising the deep crural fascia on the medial shaft of the bone. The cranial tibial, popliteus and long digital flexor muscles were reflected from the bone by sub periosteal elevation if necessary.

For humerus shaft exposure, the skin incision was made slightly medial to the cranial midline of the bone extending from the greater tubercle of the humerus proximally to the lateral epicondyle distally. After undermining the skin, an incision was made through the deep fascia along the caudal border of the brachiocephalicus muscle which was retracted cranially. Exposure of the shaft was accomplished by sub periosteal elevation of the deep pectoral and deltoideus muscle

Implant: An indigenously designed intramedullary IL nailing system implant was used for the study (Raghunath and Singh 2002). The implant included solid interlocking nails made of 316 L grade stainless steel in two different diameters and length of varying size, one end of nail was blunt and tapered and other end was provided with a key lock configuration, to attach the nail to the right angled aiming device with a help of extension rod. The nail was solid but at holes.

Nails were of two different types based on the holes patterns. One type of nail had 4 holes proximally and 4 holes distally at a distance of 10 mm each and the other type had multiple holes all through its length at a gap of 10 mm. The length of the nails for each diameter category that is 6 mm and 8 mm varied from 12 cm to 18 cm to suit the different age groups and different sizes of dogs. The aiming device made up of aluminum, was designed such that the holes on the aiming device exactly corresponded to the holes on the nail when the nail was in the medullary cavity of the bone and the aiming device remained outside the body.

The markings 12, 14, 16 and 18 on the aiming device matched to the last distal hole of the corresponding nail.

The aiming device which remained outside the body was always parallel to the nail inside the medullary cavity. The holes in the bone then could be drilled, tapped and fixed with the cortical screws through the holes in the aiming device which were designed to adapt to the drill and tap guides of appropriate sizes.

The drill size, tap size and screw diameter for the both categories of nails (6mm and 8 mm) are shown in Table 3.

Table 3: Diameter of nails and their corresponding screw diameters and drill bits and taps sizes

Length of Nail	Diameter of Nail	Screw Diameter	Drill Size	Tap Size
12,14,16,18 cm	6.0 mm	2.7mm	2.0mm	2.7mm
12,14,16,18 cm	8.0 mm	3.5mm	2.5mm	3.5mm

Position, length and number of screws were judged intra-operatively by assessing the length of bone, fracture location and configuration. The accessories of the IL nailing system included insertion handle, slotted hammer, drill bits, taps, drill sleeves, tap sleeves and depth gauge.

Fixation: Static intramedullary IL nailing was carried out and both the fracture fragments were locked. In group I (n=7) one distal transcortical screw was placed and in group II (n= 14) more than one distal transcortical screws were

placed. The number of transcortical screws used in the proximal fragment varied from one to three in both the groups.

Surgical Technique: Open fracture reduction was performed in all the cases through a standard surgical technique. After initially entering the medullary canal with a simple Steinmann pin of appropriate size using a Jacobs's chuck, the nail was inserted into the medullary cavity in a normograde fashion. The nail being attached to the right angled aiming device by extension rod remained inside the medullary canal with the aiming device exactly parallel to the nail inside the bone. Fractured ends were reduced as close as possible to the normal anatomical reduction and nail was driven further into the distal fragment. Insertion handle was then removed and nail – aiming device complex was not disturbed there-on. The distal fragment was locked first with the cortical screws of appropriate size after drilling and tapping the bone with appropriate size drill bit and tap according to the diameter of the nail. Similarly, the proximal fragment was locked. The number of proximal holes to be locked was determined intraoperatively depending upon the severity and instability of the fractured bone. Once the fixation was over, the aiming device was detached by loosening the extension rod. Ancillary support with full cerclage wires was provided to fractures that had comminution and fissures along the longitudinal axis.

Anatomic consideration for the insertion and placement of nail

Femur: Nail was introduced through the trochanteric fossa in a normograde fashion. Generally, the nail was placed so that its distal tip was not distal to the proximal pole of patella. Proximally, care was taken that the nail did not protrude dorsal to the greater trochanter where ever possible.

Tibia: Nail was placed in the tibia in a normograde fashion to prevent impingement on the structures in the stifle joint. The stifle joint was placed in 90 degree of flexion and the nail was introduced from the medial aspect of the tibial tuberosity equidistant from the attachment of the patellar tendon and cranial edge of the medial femoral epicondyle in a normograde fashion

Humerus: Nail was introduced from the cranial proximal aspect of the greater tubercle in a normograde fashion. The location of the radial nerve was considered during the fracture manipulation and nail and screw placement.

Wound Closure: Once the fracture was fixed with the desired technique, the site was copiously lavaged with normal saline to remove blood clots and other tissue debris. The fascia and subcutaneous fascia were sutured using chromic catgut #1 in a simple continuous manner. The skin incision was closed with nylon either by horizontal sutures or cross mattress sutures.

Post Operative Care: Post operatively the operated limb was given external support with a modified Robert John bandage. The bandage was changed

on alternate days and was kept for 10 days. The wound was dressed with betadine. The dogs were administered inj. Roscillox[j] (Ampicillin + Cloxacillin) @ 20 mg/kg b.w IM t.i.d for 7 days and inj. Gentamicin[k] @ 2- 4 mg/kg b.w IM b.i.d for 3 days. Analgesia was provided by Inj. Voveran[l] (Diclofenac sodium) immediately after surgery followed by tab Nimesulide[m] 100mg given PO b.i.d for 3-4 days. The clients were advised to restrict the movement of dogs to minimal for at least first 15 days. Skin sutures were removed 10-12 days after surgery. After 15 days following surgery dogs were allowed leash walk

Parameters Investigated

I. Distribution of fractures: Distribution of fractures was studied with respect to the sex, bone, age, body weight, breed, limb involved, etiology and type of fractures. The fractures were classified according to AO/ ASIF fracture classification system.

---

j- Ranbaxy Labs Ltd., New Delhi-19

k- Ranbaxy Labs Ltd., New Delhi-19

l-Novartis India Ltd. Thane, Maharashtra

m-Panacea, Biotech. Ltd., New Delhi-44

II. Intraoperative observation: During surgery the fracture configuration, displacement and overriding of bone fragments, bone loss, extent of soft tissue damage, adherence of soft tissue to the bone, ease of fracture reduction and intra operative stability were observed. Technical difficulties in implant application, reduction of the fracture fragments were noted. Anaesthetic complications, if any, were noted.

III. Clinical Observations: Clients were contacted on telephone and were asked to evaluate their pets performance with reference to the number of days after surgery, whether the dog started to touch the treated limb on ground, the extent of weight bearing while standing, walking. They were asked to evaluate the extent of limb usage, any change in gait and angular deformity and the wound healing complications. They were asked to present the dog for the follow-up on the second week following surgery for radiography and clinical evaluation. Subsequently the case was followed till bone healing was evident both clinically and radiographically for variable period.

a) Wound Condition: Surgical wound was examined for its gross appearance and healing status. The fractured limb was examined for the pain, edema and exudation. Observations were made on the day of fracture fixation and then on alternate days till dog were presented for the postoperative follow up till the sutures were removed.

b) Weight Bearing: The dogs were assessed for the weight bearing and functional usage of the affected limb after surgery. The number of days following the surgery were noted when the dogs showed signs of weight bearing.

c) Rotation: Rotation of the fractured segments was assessed clinically by comparing the configuration of the affected limb and position of the paw while standing with, contralateral normal limb.

d) Gait abnormality: Gait abnormality while standing and walking was monitored.

e) Clinical complications: Conditions like osteomyelitis, skin wound dehiscence, delayed union, mal union, non union, presence of sequestrum, sinus tract, muscle weakness and atrophy, shoulder joint and stifle joint stiffness were noticed.

f) Joint Movement: Stifle, shoulder, elbow and hip joints movement was assessed for any abnormality or stiffness clinically.

g) Haematology: EDTA vials were used for the collection of blood and 2-3 ml of blood was collected on either the day of first presentation or on the day of surgery. Subsequent samples were taken when the clients brought the pets for follow-up. In some cases the clients were asked to get the haematological evaluations done in their cities. These samples were analyzed for Hb (g %), TLC (cells/µl) and DLC (%) using standard methods.

IV. Radiography: Craniocaudal and mediolateral radiographs of the operated bone was taken immediately after surgery and there after at subsequent

intervals to assess the bone union. The radiographs were assessed for the fracture fragments apposition and reduction, implant position, time taken for initial periosteal reaction after surgery, callus formation and time taken for complete healing of bone. The immediate post operative radiograph was used to assess the distance of the distal screws from the fracture line.

VI. Implant related Complications: Complications like misdirected screws, screw bending, screw breakage, screw dislodgement, nail bending and nail breakage, failure in reduction were noted.

VII. Removal of implant: The removal of implant was considered optional and implant removal was taken up after the complete healing of the bone was evident radiographically and clinically. Incisions were given to remove screws whose position was judged by radiographs and the implant was removed from the proximal end of the bone from where it was inserted. The difficulties involved in the removal of implant were noticed and recorded.

Chapter IV

RESULTS AND DISCUSSION

The present study was conducted to evaluate and compare the clinical efficacy of the static intramedullary IL nailing with respect to placement of transcortical screws in the distal fragment of the fractured bone. The study involved the use of IL nailing system for long bone diaphyseal fracture fixation indigenously designed by Raghunath and Singh (2002). The study was conducted on 19 clinical cases of dogs with long bone fractures (n=21) and their follow-up during the period extending from Nov, 2002 to April 2004. The following parameters were recorded and results are discussed under the following headings:

4.1 Distribution of diaphyseal fractures

4.2 Implant

4.3 Intraoperative observations

4.4 Clinical Observation

4.5 Radiography

4.6 Complications

4.1 Distribution of long bone fractures

During the study, 19 clinical cases of dogs (with 21 long bone fractures) were presented for the treatment to the Small Animal Clinics, PAU, Ludhiana. The number of males (n=15) 78.9 % were significantly higher than the females (n=4) 21.05 % (Table 4, Fig 1). Similar findings were reported by Maala and Celo (1975), Mahajan (1998), Adil (2001) and Raghunath (2002). Kolata *et al* (1975) opined that low incidence among females was because they tend to remain in the home environment more readily than the males. Studies by Phillips (1979), Thilgar and Balasubramanian (1988), Patil *et al* (1991) and Bains (2000) also indicated the higher incidence of fractures in males than in females. The higher incidence of fractures in males can also be attributed to higher population and aggressive temperament of males which makes them more prone to trauma due to their wander lust activities.

Table 4: Sex wise distribution of long bone fractures

Sex	Number	Percentage
Male	15	78.9
Female	4	21.05
Total	19	100

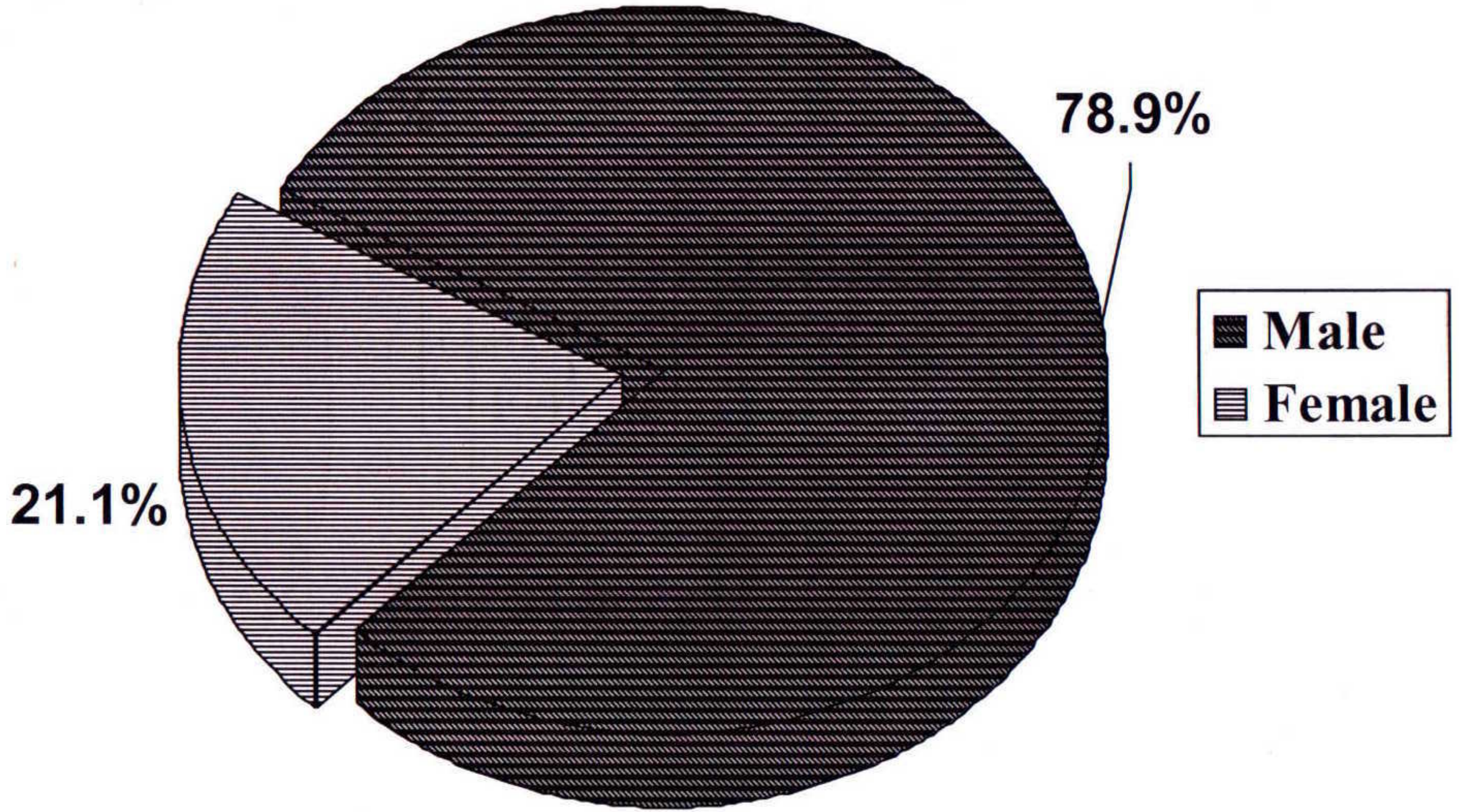


Fig 1. Sex wise distribution of long bone fractures

Among long bones, the fracture of femur had highest occurrence (n=16) 76.1 % followed by tibia (n=3) 14.28 % and humerus (n=2) 9.5% (Table 5, Fig 2). Maala and Celo (1975), Singh (1999) and Raghunath (2002) also reported femur as the most commonly affected bone followed by tibia and humerus. Kolata *et al* (1975), Phillips (1979), Balagopalan *et al* (1995), Aithal and Singh (1999) also reported similar incidence of femur fracture among long bone fractures in dogs. Maala and Celo (1975) opined that femur in spite of being most massive bone and also well protected by muscles was commonly affected because of counteracting pulls of the flexor and extensor muscles which act antagonistically.

Table 5: Bone wise distribution of long bone fractures

Bone	Number	Percentage
Femur	16	76.1
Tibia	3	14.28
Humerus	2	9.5
Total	21	100

Left side limb was involved in most of the cases (n=12) 63.15 % followed by right side (n=5) 26.5 % and bilateral involvement in (n=2) 10.5 % cases (Table 6, Fig 3).

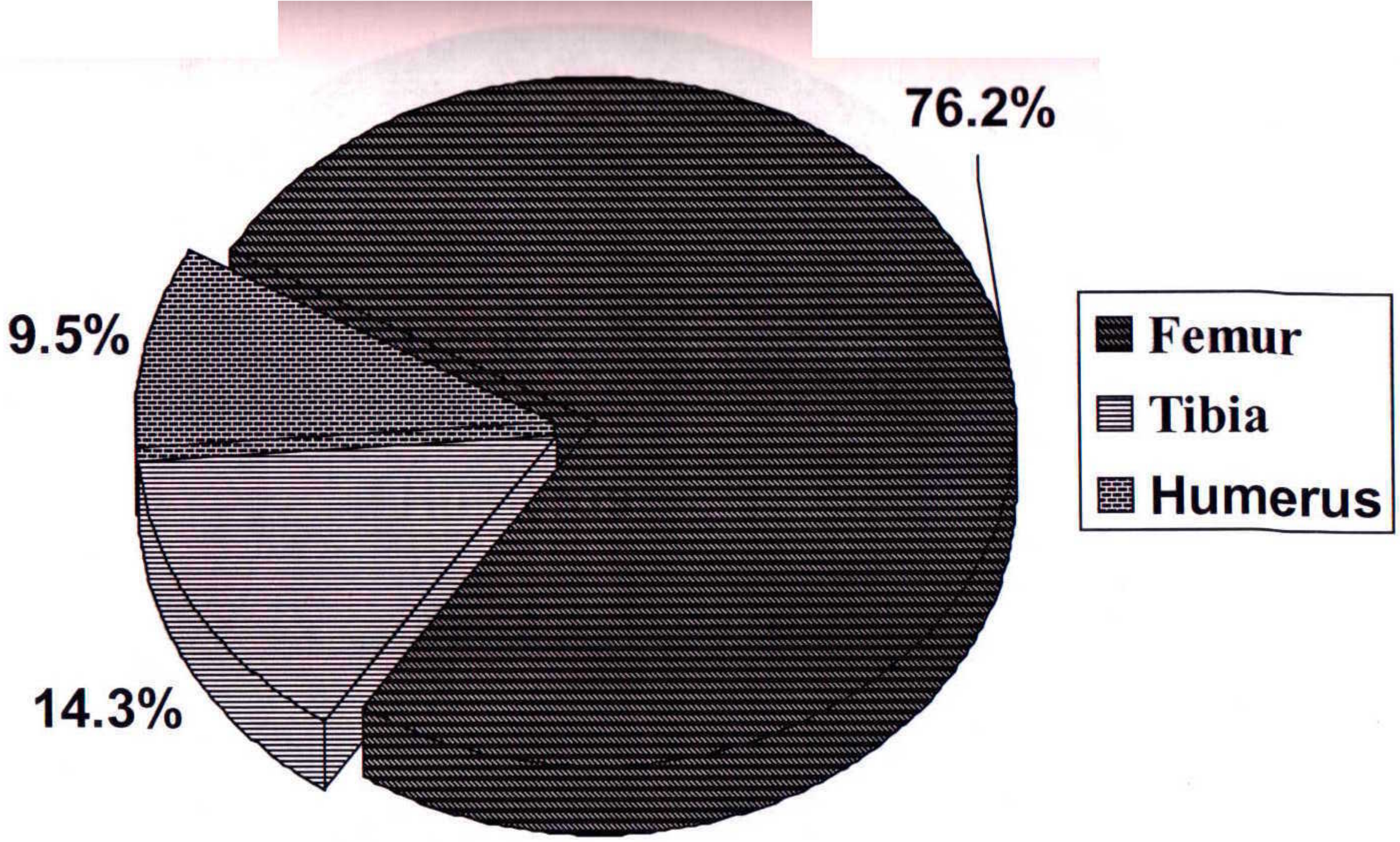


Fig 2. Bone wise distribution of long bone fractures

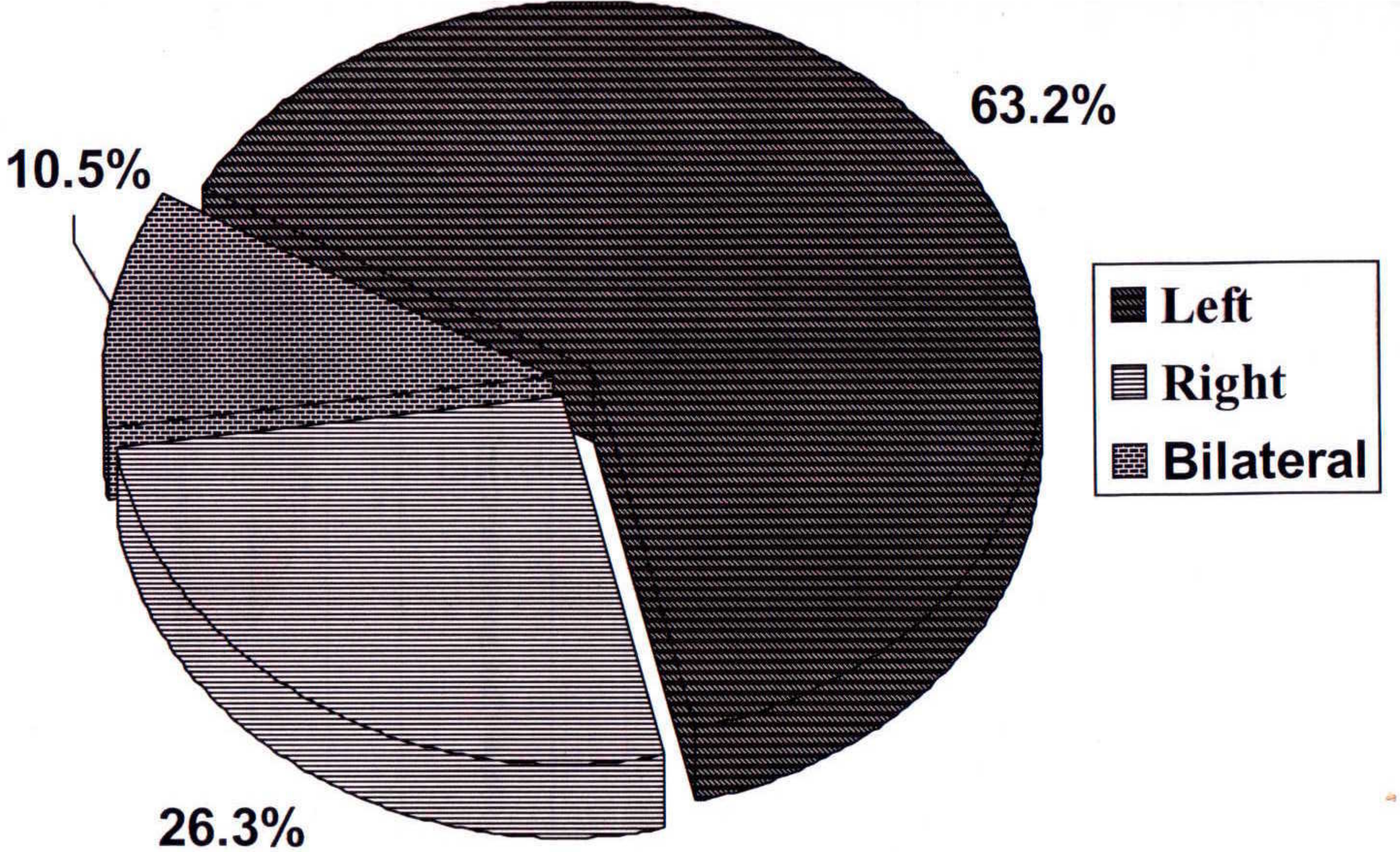


Fig 3. Limb wise distribution of long bone fractures

Among individual fractures, left femur fractures were seen in (n=10) 62.5% cases and right femur fractures were recorded in (n=6) 37.5 % cases. Among tibia, left tibia fractures were seen in (n=3) 100 % cases, and among humerus left and right bone fracture were equally distributed as (n=1) 50 % each (Table 7, Fig 4). Similar findings were reported by Mahajan (1998), Adil (2001), and Raghunath (2002). Mahajan (1998) attributed similar results during his study to left side movement of vehicles on the road in India.

Table 6: Distribution of long bone fractures according to limb involvement

Limb Involved	Number	Percentage
Left	12	63.15
Right	5	26.5
Bilateral	2	10.5
Total	19	100

Table 7: Distribution of long bone fractures among individual bones

Fracture	Number	Percentage
Left femur	10	62.5
Right femur	6	37.5
Left tibia	3	100
Right tibia	-	-
Left humerus	1	50
Right humerus	1	50

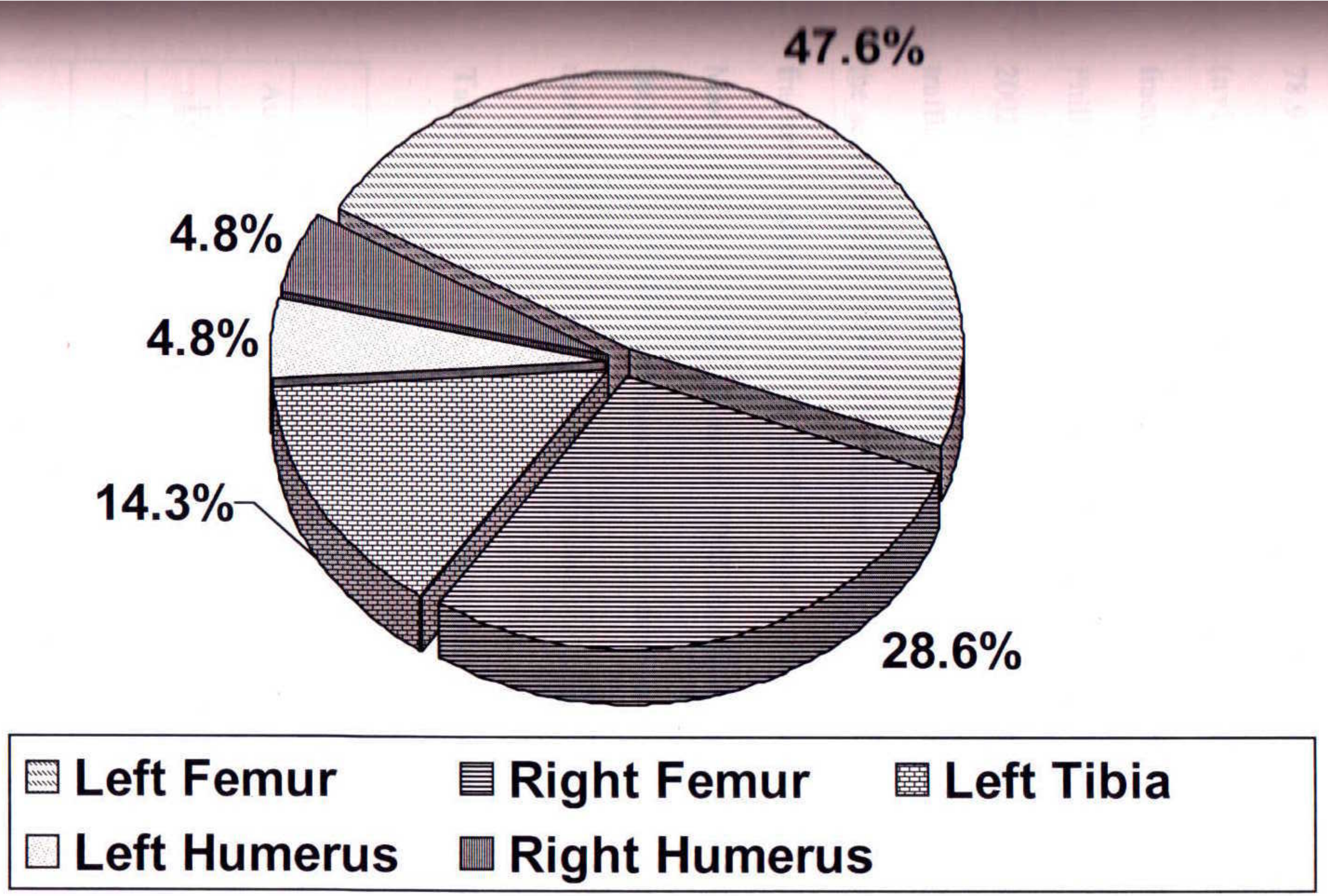


Fig 4. Individual bone wise distribution of long bone fractures

The main exciting cause of the fracture was automobile accident (n=15) in 78.9 % cases, followed by fall from height (n=3) in 15.7 % cases and abuse in (n=1) in 5.2 % cases (Table 8, Fig 5). Automobile accidents as the major cause of fractures in dogs, has also been reported by other workers (Maala and Celo 1975, Phillips 1979, Aithal and Singh 1999, Bains 2000, Adil 2001 and Raghunath 2002). The increased trend of pets in urban population and increased vehicular traffic in recent years might have contributed to this factor. Fall from height was the second cause of fracture recorded in this study. Several workers have reported fracture incidence with fall as the major etiology of injury. (Kolata *et al* 1975, Maala and Celo 1979, Mahajan 1998, Bains 2000, Adil 2001 and Raghunath 2002). The higher incidence of fall from heights in pets suggests poor managemental and keeping care of animals in urban areas.

Table 8: Distribution of long bone fractures according to etiology

Cause	Male	Female	Total	Percentage
Automobile accident	12	3	15	78.9
Fall from Height	3	-	3	15.7
Crushing injury	-	-	-	-
Abuse	-	1	1	5.2

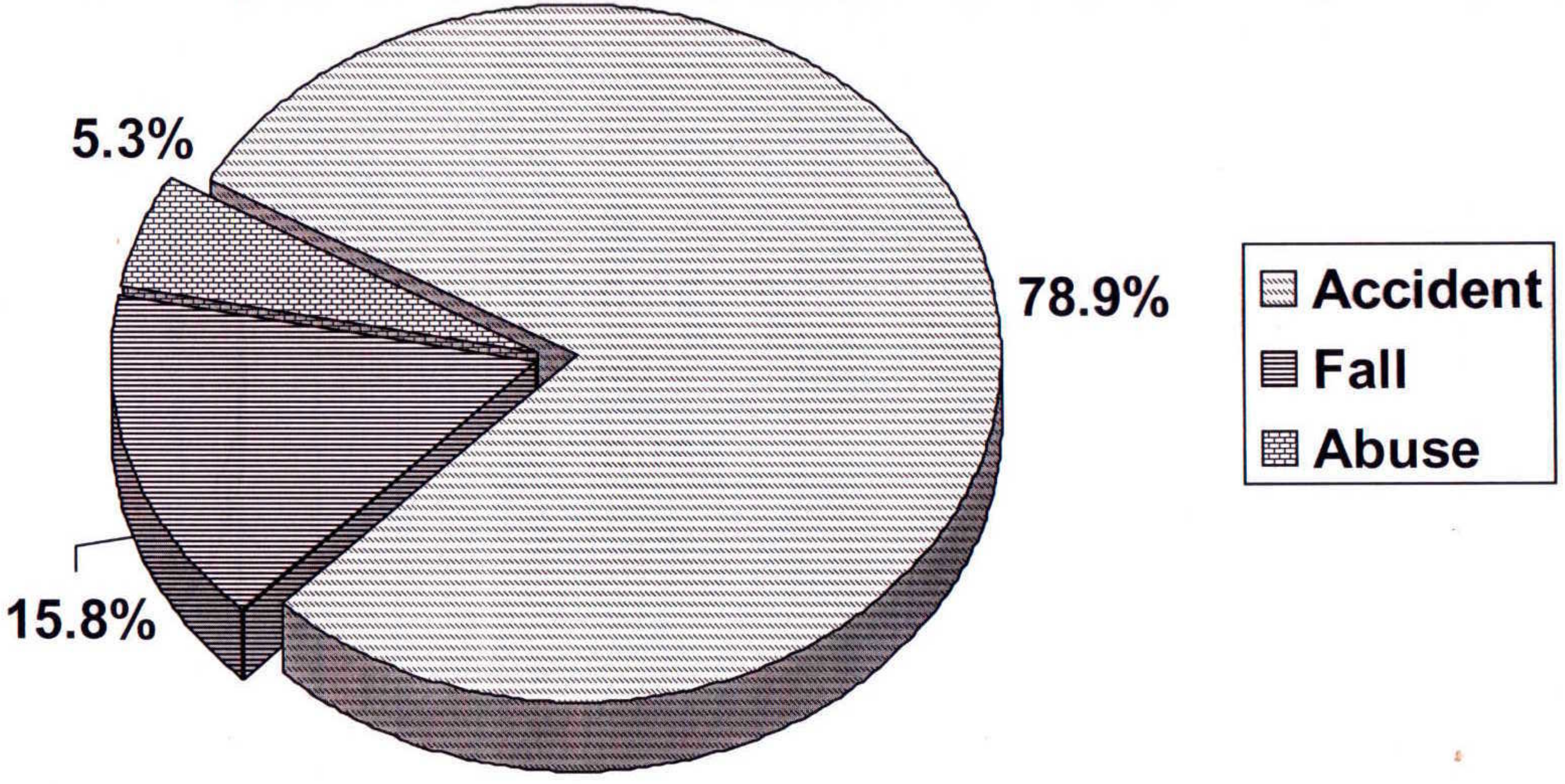


Fig 5. Distribution of long bone fractures according to etiology

The occurrence of fracture was noted in different age groups but young dogs were mostly affected (Table 9, Fig 6). The dogs less than 1 year were at high risk (n=10) i.e. 52.6 %. Among dogs under one year of age, dogs which were in age group 6-12 months (n=7) were most commonly affected. They were followed by dogs of age group 1-2 years (n=6) i.e. 31.5 %. This was mostly due to the fact that young dogs were most active and flexible than their counterparts, making them more vulnerable to injuries. (Phillips 1979, Thilgar and Balasubramanian 1988, Aithal and Singh 1999, and Raghunath 2002).

Table 9: Age wise distribution of long bone fractures

S. No.	Age group	Number	Percentage
1.	3-6 months	3	15.7
2.	6-12 months	7	36.8
3.	12-24 months	6	31.5
4.	24-36 months	-	-
5.	36-48 months	1	5.2
6.	48 months & >	2	10.5
Total		19	100

During the study heavy weight group dogs (above 20 kg b.w.) had the highest occurrence of fractures followed by medium weight group dogs (10-20 kg b.w.) and light weight group dogs (less than 10 kg b.w.) (Table 10, Fig 7).

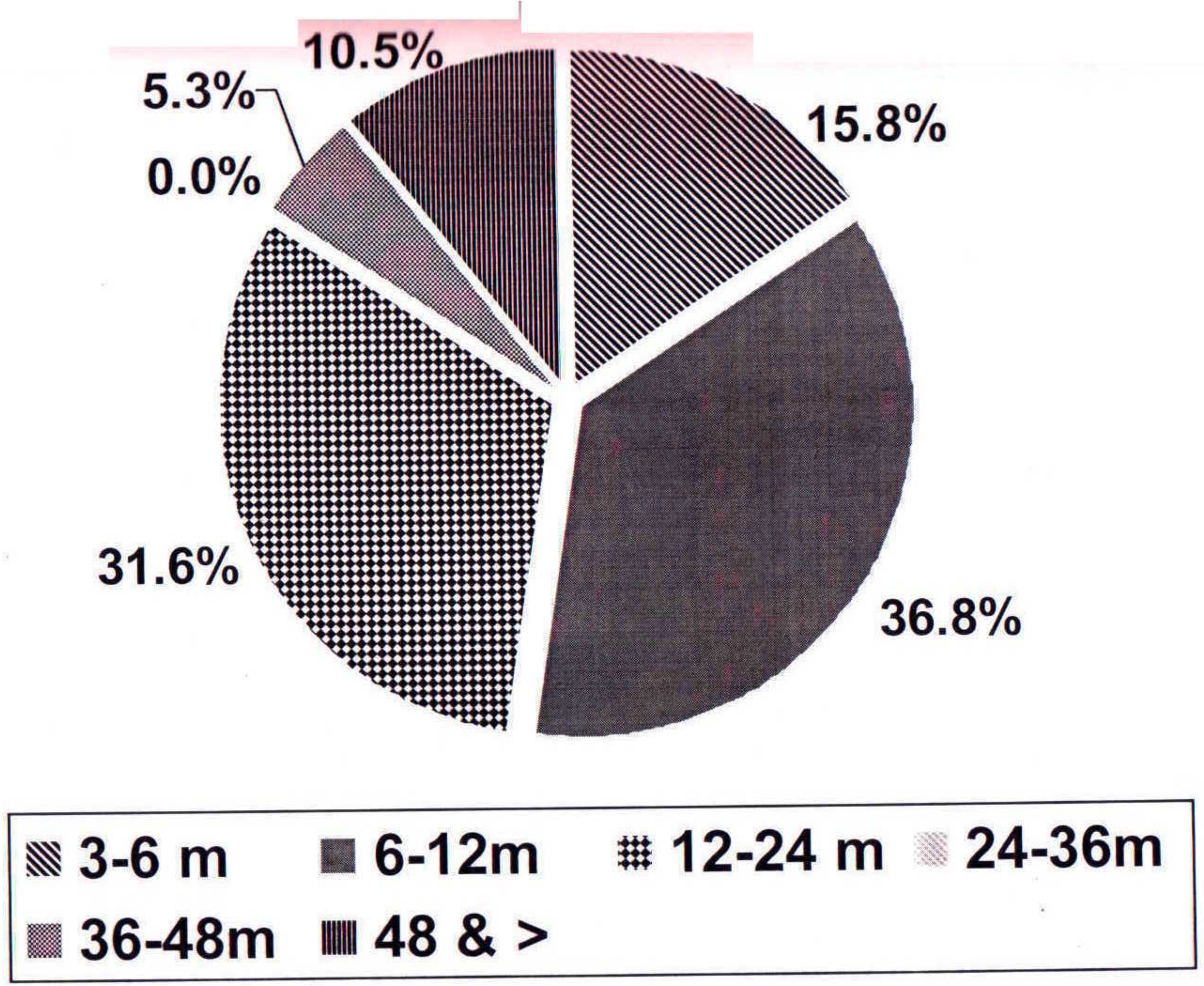


Fig 6 . Age wise distribution of long bone fractures

Table 10: Weight wise distribution of long bone fractures

S. No.	Weight group	Number	Percentage
1.	Less than 10 kg b.w.	3	15.7
2.	Medium 10-20 kg b.w.	5	26.3
3.	Heavy 20 kg b.w. and >	11	57.8
Total		19	100

During the study, in German shepherd breed, the incidence of fractures was most commonly seen (n=8) 42.1 % followed by Great Dane, Gaddi, Spitz, Labrador Retriever, Doberman with similar occurrence of (n=2) 10.5 % for all these breeds (Table 11, Fig 8). Similar results of higher incidence of fractures in German shepherd dogs were reported by Mahajan (1998) and Adil (2001).

Table 11: Breed wise distribution of long bone fracture

S. No.	Breed	Number	Percentage
1	German Shepherd	8	42.1
2.	Great Dane	2	10.5
3.	Spitz	2	10.5
4.	Grey Hound	1	5.2
5.	Doberman	2	10.5
6.	Labrador Retriever	2	10.5
7.	Gaddi	2	10.5
Total		19	100

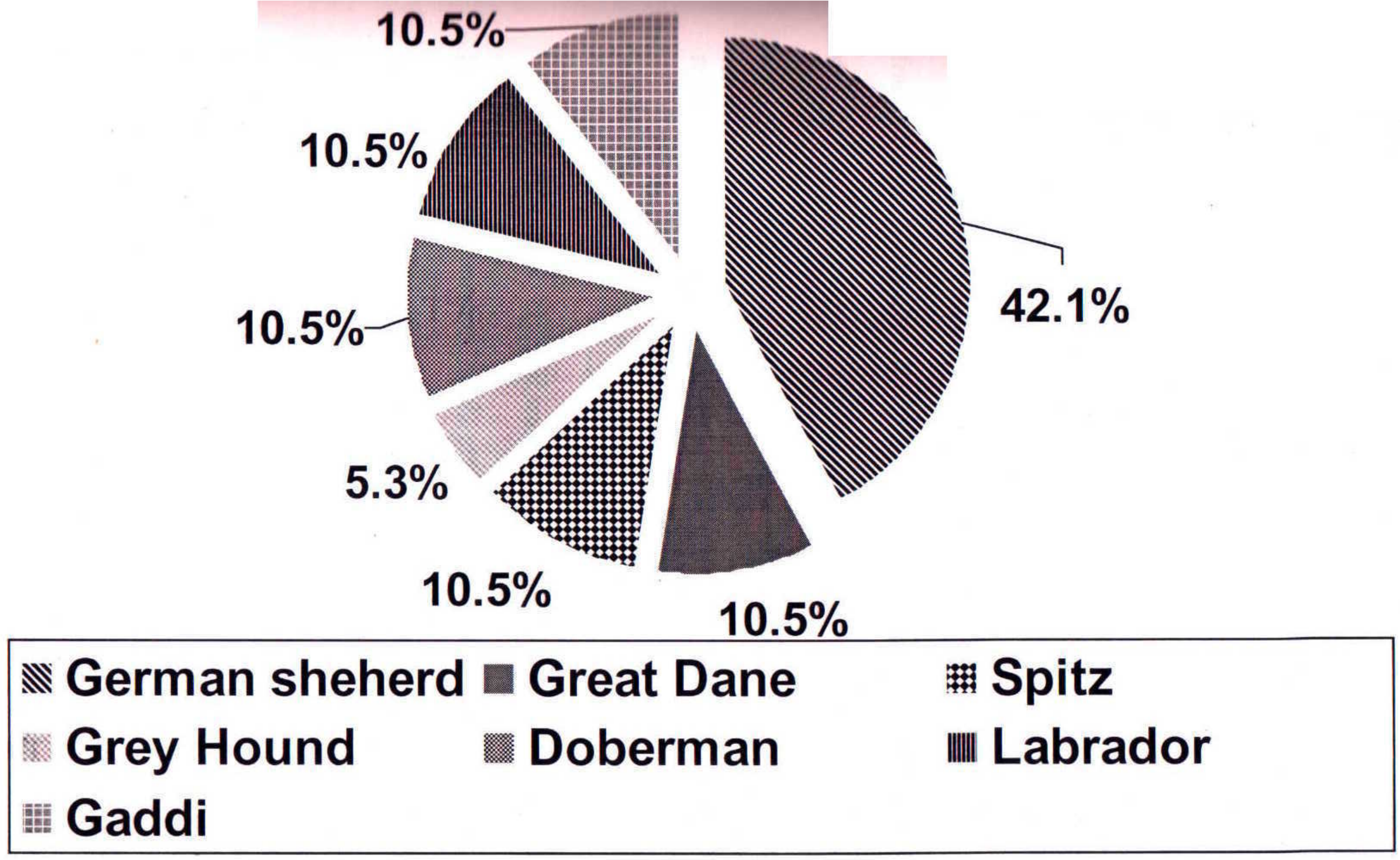


Fig 8. Breed wise distribution of long bone fractures

Classification of long bone fractures

The fractures were classified according to AO/ ASIF classification system (Table 12). This classification uses a four character alpha numeric code, the first two characters serve to localize the fracture and last two describe its morphology. There fore the first character locates the long bone: 1=Humerus, 2= Radius ulna, 3= Femur, 4= Tibia/ fibula. The second character designates the segment of the bone: 1= proximal, 2= diaphyseal and 3= distal. The third character codes for the fracture type: A= simple, B= Wedge, C= Complex. The fourth character identifies the fracture complexity: A1= incomplete, A2= oblique, A3= transverse, B1= one reducible wedge, B2= several reducible wedges, B3 non- reducible wedges, C1= reducible wedge, C2= segmental and C3= non reducible wedges (Miller *et al* 1998).

Individually, femoral fractures were found to be mostly simple (32A, 33A) in (n=10) 62.5% cases. The diaphysis was involved in (n=5) 31.25 % cases with oblique configuration and distal femur was involved in (n=5) 31.25 % cases with simple transverse configuration. In 12.5 % cases (n=2) femoral diaphysis with multiple fragments was recorded.

Among tibia, all the cases involved the diaphysis, with fracture configuration ranging from simple oblique (n=1) in 33.3 %, fragmented wedge (n=1) 33.3 %, and complex segmental type (n=1) 33.3 % cases respectively.

Table 12: Classification of long bone fractures as per AO/ ASIF classification

AO CLASSIFICATION CODE	NUMBER	PERCENTAGE
FEMUR		
32A2	5	31.5
32A3	1	6.25
32A (1-3)	1	6.25
33A1	5	31.25
32B1	1	6.5
32B3	2	12.5
32C2	1	6.25
Total	16	100
TIBIA AND FIBULA		
42A2	1	33.3
42B3	1	33.3
42C2	1	33.3
Total	3	100
HUMERUS		
12A2	2	100
Total	2	100

32A2 Femur Diaphysis Simple Oblique
32A3 Femur Diaphysis Simple Transverse
32A(1-3) Femur Diaphysis Simple Subtrochanteric Zone
33A1 Femur Distal Simple
32B1 Femur Diaphysis Wedge Spiral
32B3 Femur Diaphysis Wedge Fragmented
32C2 Femur Diaphysis Complex Segmental
42A2 Tibia Fibular Diaphysis Simple Oblique
42B3 Tibia Fibular Diaphysis Fragmented Wedge
42C2 Tibia Fibula Diaphysis Complex Segmental
12A2 Humerus Diaphysis Oblique (30*)

Among humerus both the fractures recorded were found to be diaphyseal oblique type (n=2) 100 % cases. The findings were found to be comparable with the earlier findings of Adil (2001) and Raghunath (2002) in which the incidence of simple femoral fractures was found to be highest. The system of classification was found to be very convenient to use and provided a better description of fracture morphology, which may be helpful in further fixation plans.

4.2 Implant

The implants used for the fracture fixation were IL nails that are modified intramedullary rods with transverse holes positioned at a set distance along the length to allow placement of the transcortical screws. The nails were inserted into the medullary cavity and transcortical screws were positioned into the proximal and distal fragments of the fractured bones. In human patients intramedullary nail fixation has replaced bone plating as the preferred method for internal fixation of diaphyseal humeral, femoral and tibial fractures (Brumback 1989). IL nails were often placed in closed fashion with the aid of intraoperative fluoroscopy. The need of intraoperative fluoroscopy for placement of transcortical screws delayed its advent into modern day veterinary practice. However, with the utilization of external jig which attaches the nail to facilitate placement of the transcortical screws, circumvented the need for the fluoroscopy. The development of the external jig not only reduced the equipment cost associated with the fluoroscopic aids but also reduced the radiation hazards to the operating surgeon. Although the results of several biomechanical studies evaluating this modality of fracture

fixation have been published, still little is known regarding the number of screws required for sufficient stability (Dueland *et al* 1996).

The aiming device or external jig was made up of aluminum and it could be easily sterilized and easy to handle due to its light weight. The exact arrangement of the holes corresponded to the holes in the nail, helped to lock the bone with the nail without marked difficulty. The aiming device designed for the present study had a very fair precision in almost all the cases except for misdirected screws in distal fragment in (n=3) 14.28 % cases. No single case of proximal screw missing the hole was noted. Missing of nail by screws was seen only in cases in which 6 mm diameter nail was used. The incidence of distal screw hole miss due to misdirected screw was also reported by Dueland *et al* (1999) and Raghunath (2002).

In the present study, nails were solid except at holes. No single case of nail breakage or bending was noticed. Similar findings were documented by Raghunath (2002). The 6mm and 8 mm diameter nails of varying length in each diameter category, ranging from 12, 14, 16 and 18 cm allowed its application in dogs of various age groups and sizes. The nails proved its versatility in application in breeds as small as Spitz and as large as Great Dane. The nails were successfully used in young as well as old dogs.

Both the designs of nails i.e. proximal- distal holes and multi holes nail proved its application in different types of fractures ranging from very high

subtrochanteric femoral fracture to low distal femoral fracture, simple transverse to a highly displaced multifragmented segmental femoral and tibial shaft fractures. The nails also proved its effectiveness in highly spiral fractures of humerus. Similar findings were documented by Raghunath (2002).

In the present study, 21 long bone fractures in 19 animals were treated. A 6 mm nail was used in (n=12) 63.15% dogs with (n=12) fractures and an 8 mm nail was used in (n=7) 36.8 % dogs with (n=9) fractures. The weight range of animals in which 6 mm nail was used ranged from 6.5-30 kg with an average weight of 17.2 kg. The weight range of animals in which an 8 mm nail was used ranged from 16-40 kg with an average weight of 27.3 kg.

In ten fractures only one proximal transcortical screw was used. In ten fractures two proximal transcortical screws were used. In only one case three proximal transcortical screws were used.

In group I in all the 7 cases single distal transcortical screw was used.

In group II, out of 14 fractures in 12 animals, in 11 fractures two distal transcortical screw were used and in 3 cases three distal transcortical screws were used.

In (n=6) 28.57 % cases, adjunctive stabilization with one or more full cerclage wire was done.

4.3 Intraoperative Observation

4.3.1 Anaesthesia: A common anaesthetic protocol was followed for all dogs in both the groups. Atropine sulphate was administered @0.02-0.04 mg/ kg b.w. SC 20 min before the induction of anaesthesia which helped in prevention of salivation that commonly follows the diazepam administration in dogs. Induction of anaesthesia was found to be smooth with diazepam as a pre anaesthetic @0.5 mg/kg b.w. IV and thiopental sodium; 5 % solution as a basal anaesthetic, administered IV " to effect". Maintenance was carried out with halothane; and the anesthetic protocol provided uneventful recovery in all cases. In three cases, pre medication with xylazine, ketamine and atropine sulphate combination at sedative dose to control the uncooperative dogs did not affect the outcome of induction achieved with thiopental sodium.

4.3.2 Fracture configuration, soft tissue trauma and fixation device

Fracture configuration, degree of soft tissue trauma, fixation device used, intraoperative fracture stability, ease of reduction and extent of over riding was recorded. The observations of both the groups are presented in Table 13 and 14.

4.3.3 Fracture Fixation

Fractures (n=7) in 7 dogs of group I were fixed with static intramedullary IL nail with one transcortical screw placed in the distal fragment. Fractures

(n=14) in 12 dogs of group II were fixed with static intramedullary IL nail with more than one transcortical screw placed in the distal fragment.

Intramedullary IL nail fixation was found to be ideally suited to the principles of biological osteosynthesis. The fracture environment was minimally disturbed and alignment of major fragments was achieved. Extensive soft tissue dissection and exposure was not generally required. The damage to the soft tissue, damage to the periosteal and extraosseous vascularity was minimum. Adjunctive stabilization was used in (n=6) cases to achieve normal anatomic reconstruction. The use of full cerclage wire as an adjunctive stabilization device helped in preventing or reducing fissure fracture formation. Dogs 1, 5 and 7 in group I and dogs 4, 11 and 12 in group II were successfully treated with combination of both static intramedullary IL nailing and full cerclage wiring. The standardized IL nailing system proved its high precision in fixation of various types of long bone fractures in dogs. The fixation method was found to be very simple and less time consuming. The fractures with marked over riding were found to be difficult to reduce, however, intra operative stability and reduction of fractures was found to be highly satisfactory in all the cases of both the groups. Degree of soft tissue trauma and swelling at the fracture site did not affect the reduction procedure. The passage of nails through the standard entry portals in femur, tibia and humerus, i.e. trochanteric fossa, medial aspect of anterior tibial tuberosity and cranio-

Table 13: Intraoperative observations in Group I

Dog No.	Fracture Configuration	Degree of soft tissue trauma	Extent of over riding	Ease of reduction	Fixation Technique	Intra operative Stability
1.	Tibia simple oblique fracture	Severe damage to medial aspect with bruises	Marked	Difficult	6-18-01-01[a] 2 screws- 2.7 mm + 3 F.C.W[b]	Stable
2.	Femur compd mid shaft oblique fracture with multiple irreducible chips	Marked damage to muscle bellies with marked haematoma	Marked	Difficult	6-18-02-01 3 screws- 2.7 mm	Stable
3.	Femur simple distal 3rd fracture, 10 days old	Severe muscle damage with early callus	Minimum	Easy	6-12-01-01 2 screws-2.7 mm	Stable
4.	Femur simple distal 3rd oblique fracture with a chip on caudal aspect	Severe damage to muscle bellies with significant haematoma	Moderate	Easy	6-16-01-01 2 screws -2.7 mm	Stable
5.	Tibia compd mid shaft segmental fracture	Severe damage to medial aspect of limb with an open infected wound	Moderate	Easy	6-12-01-01 2 screws 2.7 mm + 2 F.C.W	Stable

Cont... table 13.

Dog No.	Fracture Configuration	Degree of soft tissue trauma	Extent of over riding	Ease of reduction	Fixation Technique	Intra operative Stability
6.	Femur simple distal transverse fracture	Moderate damage to muscle bellies with moderate haematoma	Moderate	Easy	6-18-02-01 3 screws -2.7mm	Stable
7.	Femur simple segmental fracture	Marked swelling severe damage to muscles and marked haematoma	Marked	Difficult	8-16-02-01 3 screws 3.5 mm + 6 F.C.W	Stable

a= Interlocking Nail Diameter, Length, Number of Proximal Screws and Number of Distal Screws

b= Full Cerclage Wire

Table 14: Intraoperative observations in Group II

Dog No.	Fracture Configuration	Degree of soft tissue trauma	Extent of over riding	Ease of reduction	Fixation Technique	Intraoperative Stability
1.	Femur simple proximal subtrochanteric fracture	Severe damage to soft tissue, muscle bellies pierced by bony edges, significant haematoma	Marked	Very Difficult	8-18-01-03[a] 4 screws- 3.5 mm	Stable
2.	Humerus simple mid shaft oblique fracture	Moderate damage to muscle bellies with slight haematoma	Marked	Difficult	8-14-01-02 3 screws- 3.5 mm	Stable
3.	Femur simple mid shaft transverse interdigitated fracture	Moderate damage to muscle bellies with significant haematoma	Moderate	Easy	6-12-01-02 2 screws-2.7 mm	Stable
4.	Tibial compd segmental mid shaft fracture	Severe damage to medial aspect of limb with an open infected wound	Marked	Difficult	6-14-01-02 2 screws 2.7 mm 2 FCW[b]	Stable
5.	Humerus closed mid shaft slight oblique fracture	Moderate damage to muscle bellies with significant haematoma	Marked	Difficult	8-14-01-02 3 screws 3.5 mm	Stable

Contd… table 14.

Dog No.	Fracture Configuration	Degree of soft tissue trauma	Extent of over riding	Ease of reduction	Fixation Technique	Intra operative Stability
6.	Femur simple slight oblique proximal 3rd fracture	Marked damage to muscle bellies with significant haematoma	Marked	Difficult	6-18-01-02 3 screws -2.7mm	Stable
7.	Femur simple spiral mid shaft fracture	Marked damage to muscle bellies and muscle teared with significant haematoma	Marked	Difficult	8-18-02-02 4 screws 3.5 mm	Stable
8.	Femur simple distal 3rd fracture	Moderate damage to muscles bellies with significant haematoma	Marked	Moderate	6-16-02-02 4 screws 2.7 mm	Stable
9.	Femur simple distal 3rd fracture	Moderate damage to muscle bellies with significant haematoma	Marked	Easy	6-16-02-02 4 screws 2.7 mm	Stable
10.	Femur simple mid shaft oblique fracture	Marked swelling and haematoma	Moderate	Easy	8-18-02-03 5 screws 3.5 mm	Stable

Contd…table 14.

Dog No.	Fracture Configuration	Degree of soft tissue trauma	Extent of over riding	Ease of reduction	Fixation Technique	Intra operative Stability
11.	Bilateral femur fracture Rt- Femur simple slight oblique fracture mid shaft with small reducible chips	Marked damage to muscle bellies with significant haematoma	Moderate	Moderate	8-16-02-02 4 screws 3.5 mm	Stable
	Le-Femur simple oblique fracture with large reducible chips	Moderate damage to soft tissue	Moderate	Moderate	6-16-01-02 3 screws 2.7 mm + 2 FCW	Stable
12.	Bilateral Femur fracture Rt- Femur simple segmental fracture	Marked damage to muscle bellies	Marked	Difficult	8-16-03-02 5 screws 3.5 mm + 3 FCW	Stable
	Le- Femur simple slight oblique fracture	Less damage to muscle bellies with significant haematoma	Marked	Difficult	8-16-02-02 4 screws 3.5 mm	Stable

a= Interlocking Nail Diameter, Length, Number of Proximal Screws and Number of Distal Screws
b= Full Cerclage Wire

proximal aspect of greater tubercle were found to be safe and effective for fracture reduction. In all the cases in both the groups distal locking was done first followed by proximal locking.

During the fracture fixation with static intramedullary IL nail the proximity of the screws to the fracture line was also considered. The attempt was made that the screw placement through the nail was away from the fracture line to avoid the points of stress risers. Dueland *et al* (1996) had experimentally shown that minimum recommended distance between screws and fracture site using 6 mm and 8 mm nail is 2 cm. This recommendation however held very little practicality in clinical situations where very low distal femur fractures offered very little space for the passage of distal transcortical screw so the single transcortical screw that was used in such distal fractures in distal fragments some times was very close to the fracture line.

4.3.4 Range of Fractures

The technique was successfully used in fractures of various kinds. The simple fractures as well as the compound fractures were successfully treated. In group I the fractures varied in configuration from simple transverse to highly unstable and displaced segmental/comminuted fractures. Raghunath and Singh (2002) also treated such comminuted fractures with static intramedullary IL nailing in dogs along with use of adjunctive device such as full cerclage wires.

Endo *et al* (1998) suggested that intramedullary IL nail has the better fixation over ordinary intramedullary fixation because the interlocking nail could resist bending force and screw could resist force caused by rotation.

In group II, fractures ranging from very high subtrochanteric femur fracture to very low distal femur fractures, mid shaft oblique humerus fractures and tibial fractures of varied configuration were treated. Similar range of fractures were treated by several other workers like Dueland *et al* (1999), Endo *et al* (1998), Moses *et al* (2002) and Raghunath (2002).

4.4 Clinical Observations

4.4.1 Wound Healing

4.4.1.1 Group I

Post operatively the surgical wound was cleaned with betadine in all the cases and antiseptic dressing with betadine was applied. Modified Robert John bandaging was applied which was changed on alternate days up to 10-12 days. Slight discharge was seen in all the cases up to 3rd day from the suture line. The swelling at the incision site subsided subsequently on 7th to 10th post operative day. Surgical wounds healed with first intention in all the dogs except dog 5 in this group where the wound infection developed. The dog due to its unrelenting behavior licked the site of incision continuously and impaired the healing process. The post operative dressing with betadine was continued till the wound healing

was evident. Later on the same dog developed osteomyelitis at 4 month post operatively. The wound healing in this dog was found to be slow and impaired due to its old age (12 years).

4.4.1.2 Group II

In this group similar post operative care was carried out and modified Robert John bandage was done on alternate days. Mild edematous swelling was noticed in all the cases which subsided on 7^{th} to 10^{th} post operative day. In dog 1, excessive fluid was present althrough the incision line and this subcutaneous fluid were drained on 3^{rd} post operative day by removing the last suture. A hypodermic needle of 18 G was used to flush the wound with betadine diluted in saline and wound healed uneventfully by 12^{th} post operative day.

Dog 7 opened the sutures on 2^{nd} post operative day and resuturing was done after cleaning the open wound with betadine. The wound healed by 12^{th} post operative day.

In dog 12, soft tissue infection was evident after 1 month post operatively. The tract of infection was noticed from the point of entry of nail i.e. trochanteric fossa. The dog was administered antibiotic Cefadroxil @ 20 mg/kg b.w. P.O at 12 hr interval for 21 days. The signs of infection such as draining pus, pain and lameness subsided. The antibiotic was withdrawn. But a month later, on direct examination, the infection was still evident and radiographically osteolytic changes were evident.

In all other cases in this group, the wound healing occurred by first intention without complications.

In both the groups the swelling was observed at the wound site as a result of acute inflammatory changes occurring as a result of high energy trauma. The swelling and edema subsided on 7^{th}- 10^{th} post operative day. The stage of inflammation begins immediately after the fracture and persists till the initiation of cartilage or bone formation (Arnoczky *et al* 1985).

Modified Robert John bandaging was found to be effective to provide joint immobility and produce the even pressure there by preventing the post operative edema that frequently arises due to disruption of soft tissue by bony edges. The static intramedullary IL nail irrespective of number of transcortical screws and adjunctive stabilization was found to be free from the complications associated with wound healing and can be successfully used in open and infected fractures. A similar recommendation for use of static intramedullary IL nailing for stabilization of unstable infected fractures has been made by Muir and Johnson (1996).

4.4.2 Weight Bearing

4.4.2.1 Group I

In group I, almost all the dogs were able to touch the toe on the ground on 2^{nd} or 3^{rd} post operative day. Most of the dogs could keep the paw on ground on 3^{rd} or 4^{th} post operative day. Most of the dogs were able to walk with slight limping on 10^{th} post operative day. No signs of rotational deformity were seen in

any case except for mild deformity in dog 3. However direct examination of the same dog, 4 months after surgery revealed excellent clinical outcome with unnoticeable rotational deformity while standing, walking or even running. Dog 5 and 7 with multiple fracture fragments were also able to walk after 10th post operative day. The dogs achieved full usage of affected limb as early as 15th post operative day.

The dog 5 which developed osteomyelitis and 4 month post operative radiograph revealed osteolytic changes with marked bone loss on the caudal aspect was able to walk without much difficulty. Similar findings were also reported by Moses *et al* (2002), who had used static intramedullary IL nails for stabilization of open and closed humerus fractures in dogs and cats which were associated with low incidence of osteomyelitis. However Muir and Johnson (1996) reported use of IL nail for the stabilization of a femoral fracture in dog with severe osteomyelitis. Brumback *et al* (1999) concluded that immediate weight bearing after stabilization of a comminuted fracture of a femoral shaft treated with static intramedullary IL nail was safe. Similar results were seen with dog 7 of this group in which highly displaced unstable segmental femur fracture was repaired and dog was able to put weight on the affected limb on 2nd post operative day. The implant was stable enough to bear the stress of early weight bearing. Such early return of limb functioning has been observed by Durall *et al* (1994), Moses *et al* (2002) and Raghunath and Singh (2002). The rapid return of function seen with this treatment modality could be attributed to stability provided by the implant.

Table 15: Clinical Summary of dogs in Group I (n=7)

Signalment	Implant	Adj Device	Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome[c]
1. GSD-male-42m-40kg, tibia compd oblique fracture	6-18-01-01[a] 2 screws-2.7 mm	3 F.C.W[b]	Distal screw miss	15th day	12 weeks	3rd post-op day	Excellent
2. GSD-male-12m-28kg,femur simple mid shaft oblique fracture with few irreducible chips	6-18-02-01 3 screws-2.7 mm	--	Distal screw miss	15th day	12 weeks	3rd post-op day	Excellent
3. Doberman-male-4m-6.5kg, femur simple distal 3rd fracture, 10 days old	6-12-01-01 2 screws-2.7 mm	--	--	10th day	12 weeks	5th post-op day	Excellent
4. Spitz-male-18 m-10kg, femur simple distal 3rd oblique fracture with a chip on caudal aspect	6-16-01-01 2 screws - 2.7 mm	--	10th day radiograph revealed distal screw bend, 1m revealed screw break	10th day	12weeks bridging callus sign of delayed union	2nd post-op day	Excellent

Contd...table 15.

Signalment	Implant	Adj. Device	Implant Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome
5.Spitz-male-12 yrs-7kg, tibia compd mid shaft segmental fracture	6-12-01-01 2 screws 2.7 mm	2 F.C.W	--	10^{th} day	Evidence of osteomyelitis at 4 m post-op radiograph	3^{rd} post-op day	Fair
6. Gaddi-female-8 m-30kg, femur simple distal transverse	6-18-02-01 3 screws - 2.7mm	--	Distal screw bend	15^{th} day	Complete bridging callus at 12 weeks	3^{rd} post-op day	Excellent
7. GSD-male-12m-30 kg-femur simple segmental fracture	8-16-02-01 3 screws 3.5 mm	6 F.C.W	Distal screw bend	15^{th} day	Complete cortical continuity at 16 weeks	2^{nd} post-op day	Excellent

a= Interlocking Nail Diameter, Length, Number of Proximal Screws and Number of Distal Screws
b= Full Cerclage Wire
c= Grading scheme for Clinical Outcome as per Fox *et al* (1995)

Table 16: Clinical Summary of dogs in Group II (n=12)

Signalment	Implant	Adj Device	Implant Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome[c]
1. GD-male-11m-40kg, Femur simple proximal subtrochanteric fracture	8-18-01-03[a] 4 screws - 3.5mm	--	Proximal screw dislodged, Proximal distal screw break	10th day	12 weeks	3rd post-op day	Excellent
2. GSD-male-10m-25kg,humerus simple mid shaft oblique fracture	8-14-01-02 3 screws - 3.5 mm	--	--	--	Follow up lost	2nd post-op day	Follow up lost
3. Doberman-male-3m-8kg, femur simple mid shaft transverse interdigitated fracture	6-12-01-02 3 screws-2.7 mm	--	Distal of the two distal screw backed out from far cortex	15th day	12 weeks	2nd post-op day	Excellent
4. Gaddi-male-6 yrs-25kg, tibia compd segmental mid shaft fracture	6-14-01-02 3 screws - 2.7 mm	1 F.C.W[b]	--	1m radiograph revealed Periosteal reaction	8 weeks radiograph reveals bridging callus	3rd post-op day	Excellent

Contd... table 16.

Signalment	Implant	Adj. Device	Implant Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome
5.GSD-male-5 m-20 kg, humerus simple mid shaft slight oblique fracture	8-14-01-02 3 screws 3.5 mm	--	--	15th day	Cortical continuity at 8 weeks	2nd post-op day	Excellent
6. Grey Hound-female-6 m-15kg, femur simple slight oblique proximal 3rd fracture	6-18-01-02 3 screws - 2.7mm	--	--	15th day	Complete bridging callus at 12 weeks	2nd post-op day	Excellent
7. GSD-male-12m-30 kg-femur simple spiral mid shaft fracture	8-16-02-02 4 screws 3.5 mm	--	--	15th day	Complete cortical and medullary continuity at 16 weeks	2nd post-op day	Excellent
8. Lab-male-6 m-15 kg, femur simple distal 3rd fracture	6-16-02-02 4 screws 2.7 mm	--	Misdirected distal screw	15th day	Complete callus at 8 weeks	2nd post-op day	Excellent

Contd...table 16.

Signalment	Implant	Adj. Device	Implant Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome
9. Lab-male-6 m-15 kg- femur simple distal 3rd fracture	6-16-02-02 4 screws - 2.7 mm	--	Proximal of the two distal screw break	10th day	Callus formation at 6 weeks	5th post-op day	Excellent
10. GD-male-12m-40kg-femur simple mid shaft oblique fracture	8-18-02-03 5 screws- 3.5 mm	--	--	10th day	Cortical and medullary continuity at 8 weeks	2nd post-op day	Excellent
11.GSD-male-6 m-20kg- Bilateral femur fracture Rt- Femur simple slight oblique mid shaft fracture with small reducible chips	8-16-02-02 4 screws- 3.5 mm	--	Collapse of reduction at 4 weeks	---	Excessive bridging callus	2nd post-op day	Poor
Le Femur simple oblique fracture with large reducible chips	6-16-02-03 5 screws 2.7 mm	4 F.C.W	Collapse of reduction at 4 weeks	---	Excessive bridging callus	2nd pot-op day	Poor

Contd...16.

Signalment	Implant	Adj. Device	Implant Related Complication	Sign of Periosteal Reaction	Radiographic Union	Weight Bearing	Clinical Outcome
12. GSD-female-12 m-16kg, Bilateral femur fracture							
Rt- Femur simple segmental fracture	8-16-03-02 5 screws-3.5 mm	3 F.C.W	----	20th day	Excessive Callus at 3 m, evidence of osteomyelitis at 4 mo radiograph	2nd pot-op day	Good
Le- Femur simple slight oblique fracture	8-16-02-02 4 screws 3.5 mm	---	---	20th day	Callus formation evident at 12 weeks	2nd pot-op day	Good

a= Interlocking Nail Diameter, Length, Number of Proximal Screws and Number of Distal Screws
b= Full Cerclage Wire
c= Grading scheme for Clinical Outcome as per Fox *et al* (1995)

4.4.2.2 Group II

Almost similar results were seen in group II. The dogs were able to touch the toe on the ground by 2nd or 3rd post operative day. The functional return of limbs was seen mostly on 10th post operative day when the dogs were able to walk without any pain and lameness in almost all the cases except dog 11, in which the reduction failed when dog jumped from height on 2nd post operative day. The normal limb function could not be achieved in this case.

No rotational deformity and limb shortening was observed in any case. Gait abnormalities were absent in almost all the cases except dog 11 in which dragging of left paw was seen at 1 month post operative examination. This defect was attributed to the failure of reduction and complete dislodgement of screws from implant into the surrounding soft tissue. The loss of reduction could be attributed to immediate weight bearing in bilateral femur fracture when early callus formation was not evident. Bucholz *et al* (1987) suggested that risk of fatigue failure in such cases can be reduced by using nails of larger diameter and by avoiding the early weight bearing till the fractured bone has regained 50 % of its original stiffness through healing to accommodate weight bearing without risk of fatigue failure of the implant.

In both the groups joint movements i.e. stifle and elbow joint movements were found to be normal. The hip joint and shoulder joint did not show any sign of pain during weight bearing, walking or even running in all the cases.

In both the groups the fixation modality was effective in providing an early return of limb function. The animals in both the groups showed signs of early ambulation. This could be due to initial load bearing properties of nails until the initial bridging callus was evident and later on as a load sharing property, transmitting weight through the bridging callus. The early weight bearing and prompt return to normal function also prevented the muscle atrophy in the treated animals. Absence of joint stiffness, rotational deformities and limb shortening further added to normal limb usage of the affected limbs while standing, walking and running in all the cases. Similar findings of early weight bearing and complete functional usage of the affected limb were reported by Durall and Diaz (1996), Endo *et al* (1998), Moses *et al* (2002), Duhautois (2001) and Raghunath (2002).

The results suggested that static intramedullary IL nailing irrespective of number of transcortical screws used in the distal fragment was free from complications associated with other fixation modalities like delayed return of normal function, joint stiffness, pin migration, rotational deformities, limb shortening, gait abnormalities due to joint impingement, sciatic or brachial plexus entrappement. The static intramedullary IL nailing provided early weight bearing and normal functional usage of the affected limb in 8- 10^{th} post operative day (Table 15, 16).

4.4.3 Haematology

Blood samples were taken preoperatively in all the cases and post operatively in dogs at the time of post operative examination at variable intervals.

4.4.3.1 Group I

In group I, the haematological values were within the normal range in all the dogs (Table 17). In one case, marginal leucocytosis was seen but there were no signs of any infection or osteomyelitis on clinical examination. In dog 5, signs of clinical osteomyelitis were seen at 4 month post operative examination however the blood parameters of this dog were within normal range at this stage.

4.4.3.2 Group II

Similar trends were seen in group II (Table 18, 19). Haematological parameters followed similar trend as observed in wound healing. Leucocytosis (due to neutrophillia) occurs in major and minor surgical procedures where there is corticosteroid release seen in stress, pain and anaesthesia. In such cases the stickiness of the neutrophils to vascular endothelium is reduced thereby increasing the circulatory neutrophil pool (CNP) (Sastry 1998). Similar haematological trends were noticed by Adil (2001) and Raghunath (2002).

4.5 Radiography

Preoperative radiographs were taken in all the clinical cases. Both medio-lateral and cranio-caudal views were taken to determine the fracture configuration, and the length and diameter of the nail to be used for fracture fixation. The radiography of the operated limb was done immediate post operatively to assess the fracture reduction and then at variable periods. The radiographs were examined for fracture reduction, fracture healing and implant related complications.

Table 17: Haemetological values Group I

Dog No.	Preoperative						
	Hb %	TLC	DLC				
			N	L	B	M	E
1.	15.5	10600	83	15	-	-	2
2.	10.0	9400	79	18	-	-	3
3.	12.0	13800	68	28	3	-	-
4.	12.0	6800	74	21	1	-	5
5.	9.2	11200	76	23	-	-	1
6.	10.0	8400	72	24	-	-	4
7.	10.5	11300	73	25	-	-	2
Dog No.	**Postoperative**						
1.	14.5	10800	78	19	-	-	3
2.	11.4	9800	81	17	-	-	2
3.	13.0	12500	77	20	-	-	3
4.	11.5	7300	72	19	-	1	8
5.	10.0	7700	74	23	-	1	2
6.	12.0	7500	74	22	-	2	1
7.	11.0	9500	71	26	-	1	2

Table 18: Haemetological values Group II

Dog No.	Preoperative						
	Hb %	TLC	DLC				
			N	L	B	M	E
1.	11.0	11200	76	20	-	3	1
2.	11.0	6500	68	31	-	-	1
3.	10.0	14800	75	24	-	-	1
4.	11.5	7600	74	24	-	1	1
5.	7.5	7100	74	24	-	-	2
6.	13.0	10600	73	24	-	-	3
7.	12.0	8700	79	20	-	1	1
8.	-	-	-	-	-	-	-
9.	-	-	-	-	-	-	-
10.	10.5	11300	73	25	-	-	2
11.	12.5	11100	75	23	-	1	1
12.	9.5	7600	73	25	-	-	2

Table 19: Haemetological values Group II

Dog No.	Postoperative						
	Hb %	TLC	DLC				
			N	L	B	M	E
1.	12.0	11400	74	22	-	1	3
2.	-	-	-	-	-	-	-
3.	12.0	10400	68	24	-	2	6
4.	11.0	8400	76	22	-	1	1
5.	7.9	7200	71	27	-	-	2
6.	13.0	12600	75	23	-	-	3
7.	12.2	10100	78	21	-	1	-
8.	10.9	9700	68	32	-	-	-
9.	11.2	9600	72	25	-	-	2
10.	11.0	9500	71	26	-	-	2
11.	11.8	12200	74	24	1	-	1
12.	10.5	8600	74	26	-	-	-

4.5.1 Fracture Reduction

4.5.1.1 Group I

Fracture reduction was found to be satisfactory in all the 7 cases. In dog 2, the irreducible chips were left *in situ* around the fracture fragments which were evident in immediate post operative radiographs (Fig 9, 10); later on these chips were incorporated in the bridging callus. Dueland *et al* (1999) suggested that absolute anatomical reconstruction of the diaphysis may not be necessary in fractures treated with intramedullary IL nails. Moses *et al* (2002) also opined that when the principles of biological osteosynthesis were followed the undisturbed fragments of highly unstable comminuted fractures were noted to be rapidly incorporated into the fracture callus. In dog 4, the immediate post operative radiograph revealed slight caudal displacement of the proximal fragment (Fig 11, 12). There was a small gap between the two fracture fragments due to bone loss which could not be eliminated even after reduction and fixation. In dog 5, highly unstable segmental tibial fracture with a longitudinal split in distal fragment (Fig 13) was satisfactorily repaired with one distal transcortical screw and two full cerclage wires (Fig 14). In dog 7 of this group, a highly unstable femoral segmental fracture was reduced satisfactorily with one distal transcortical screws and 6 full cerclage wires (Fig 15, 16). All the dogs had satisfactory fracture reduction as seen in the immediate post operative radiograph. The results suggested that use of single transcortical screw in distal fragment provided adequate implant stability immediate post operatively in wide range of fractures.

Fig 9: Pre operative radiograph (lateral view), mid shaft slight oblique femur fracture with multiple irreducible chips (arrow) (G-I, D-2).

Fig 10: Immediate post operative radiograph (craniocaudal view), showing fixation of fracture fragments with irreducible chips left *in situ* (arrow) (G-I, D-2).

Fig 11: Pre operative radiograph (lateral view), distal 3rd femur fracture (G-I, D-4).

Fig 12: Immediate post operative radiograph (lateral view), showing fracture fixation with caudal displacement of proximal fragment (arrow) (G-I, D-4).

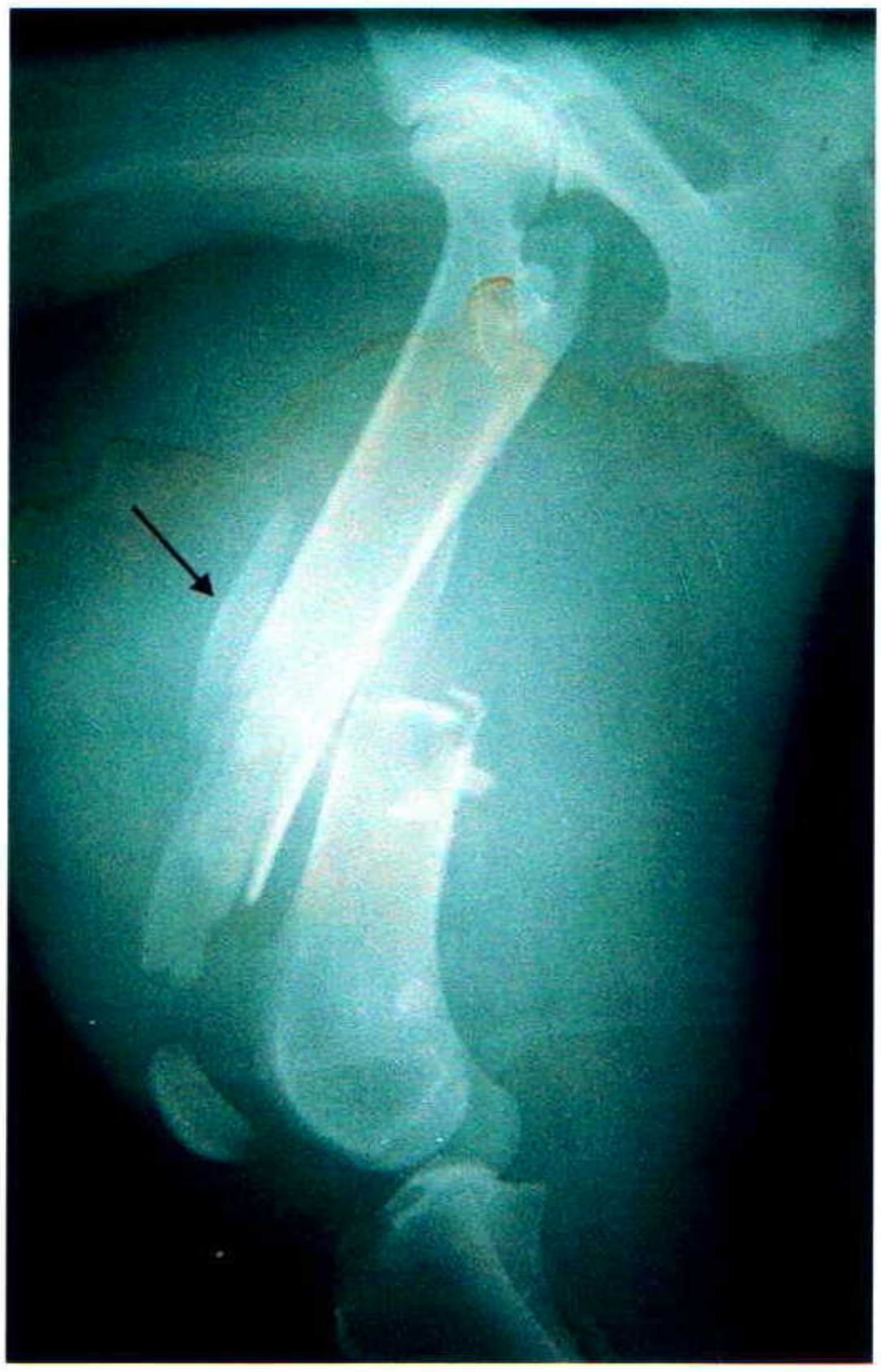


Fig. 9

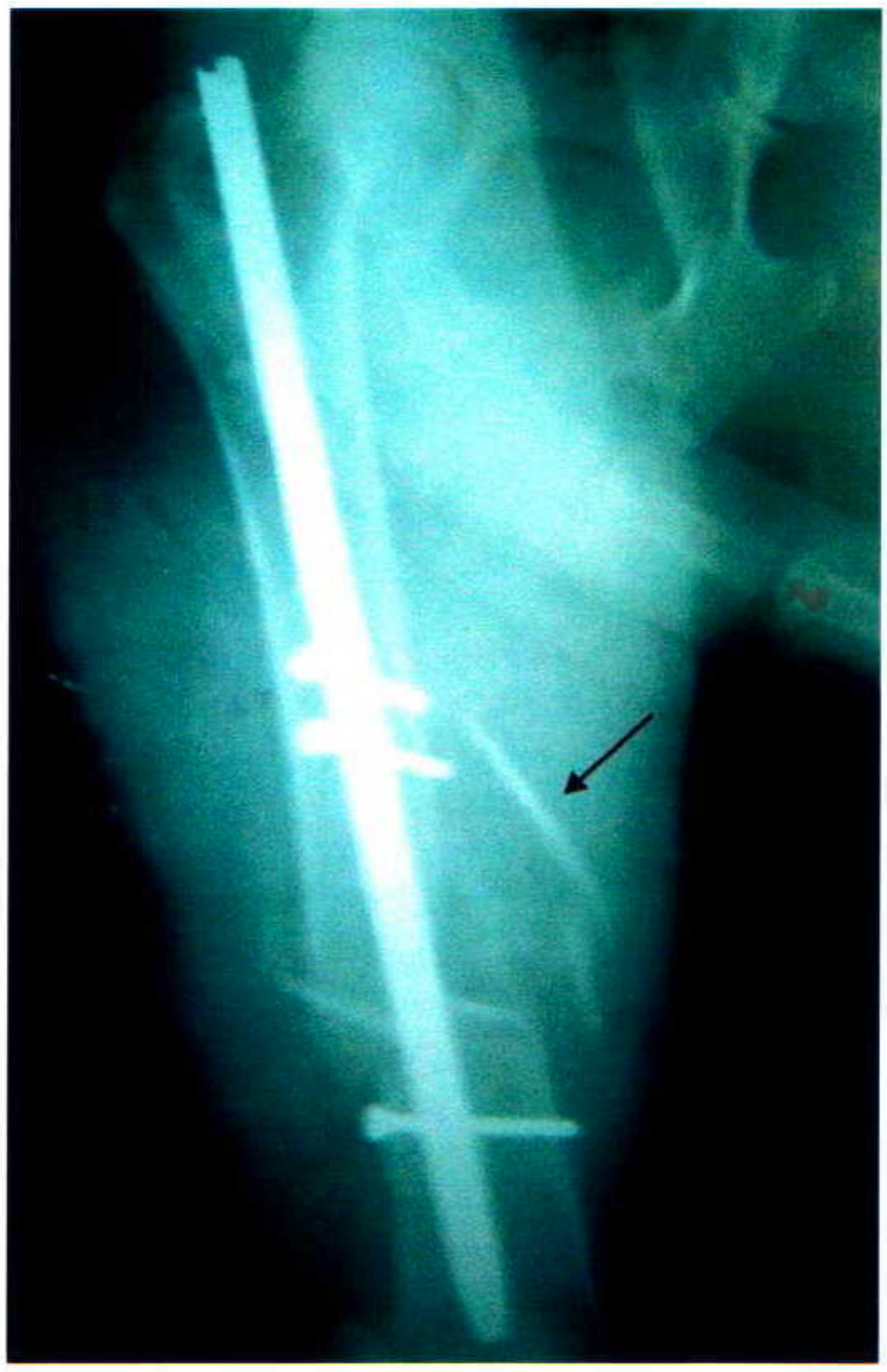


Fig. 10

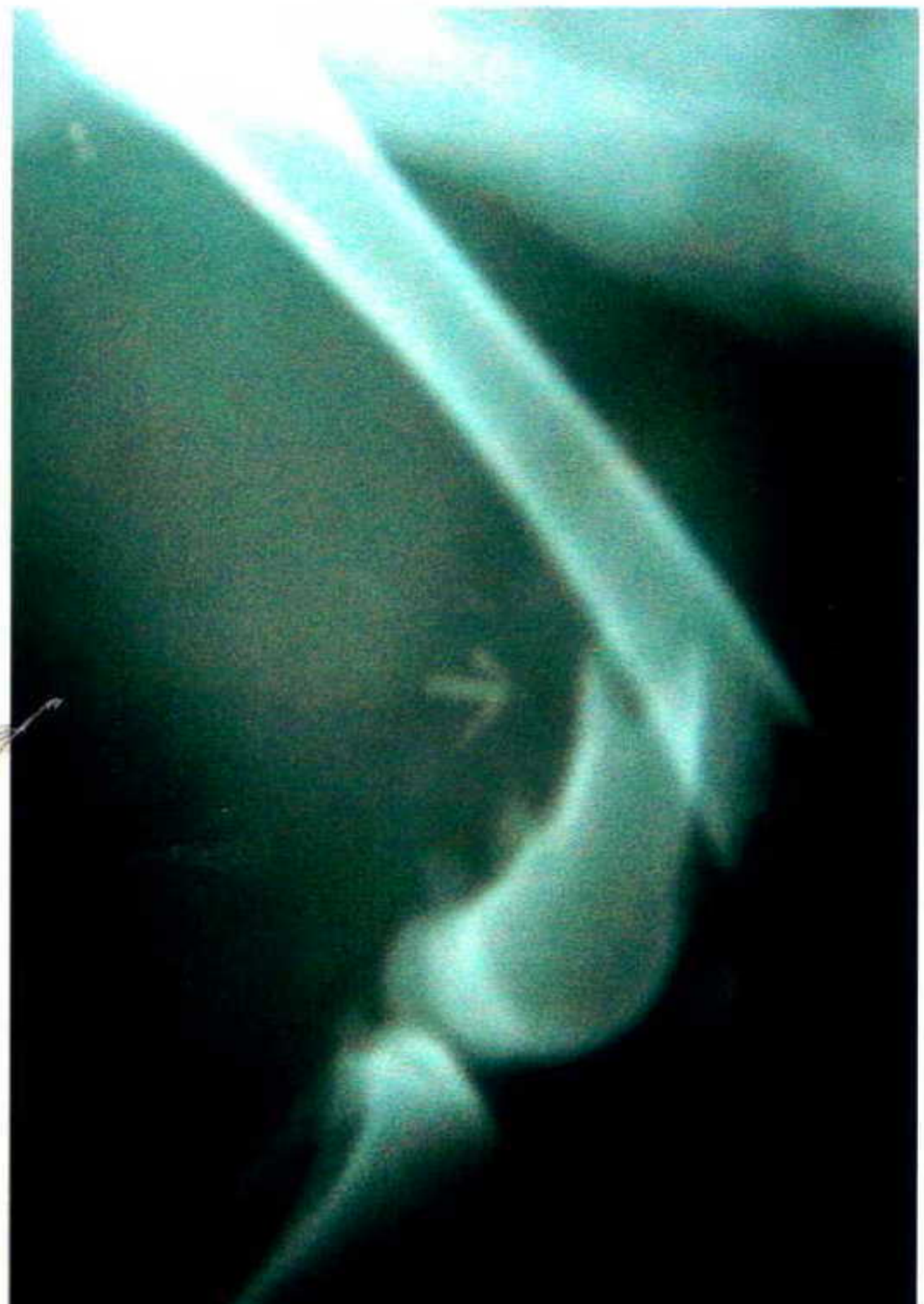


Fig. 11

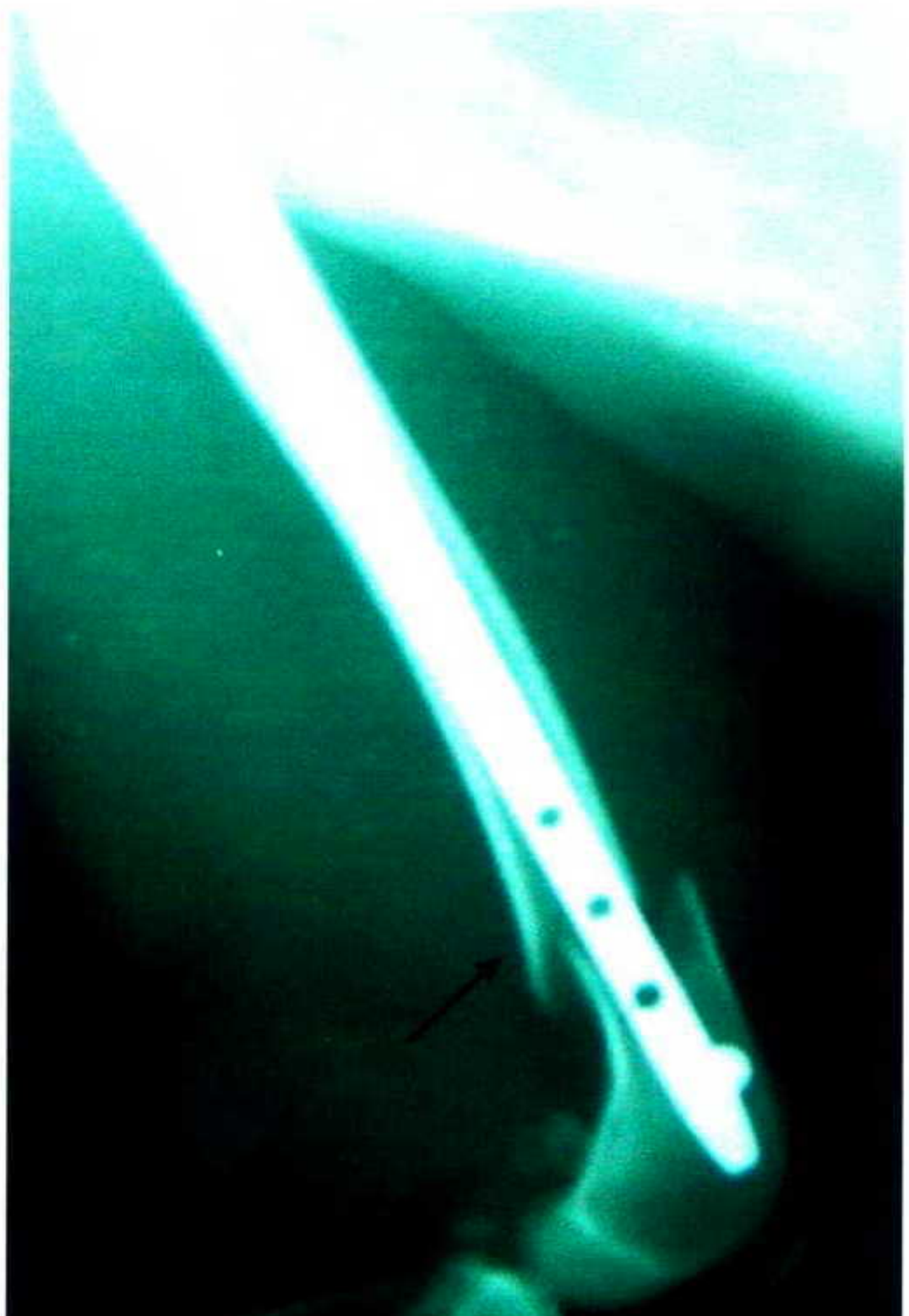


Fig. 12

Fig 13: Pre operative radiograph (craniocaudal view), midshaft segmental tibial fracture with a longitudinal split in distal fragment (arrow) (G-I, D-5).

Fig 14: Immediate post operative radiograph (lateral view), showing fixation with static intramedullary IL nailing and two full cerclage wires (G-I, D-5).

Fig 15: Pre operative radiograph (lateral view), femur segmental fracture (G-I, D-7).

Fig 16: Immediate post operative radiograph (lateral view), showing fixation with static intramedullary IL nailing and 6 full cerclage wires (G-I, D-7).

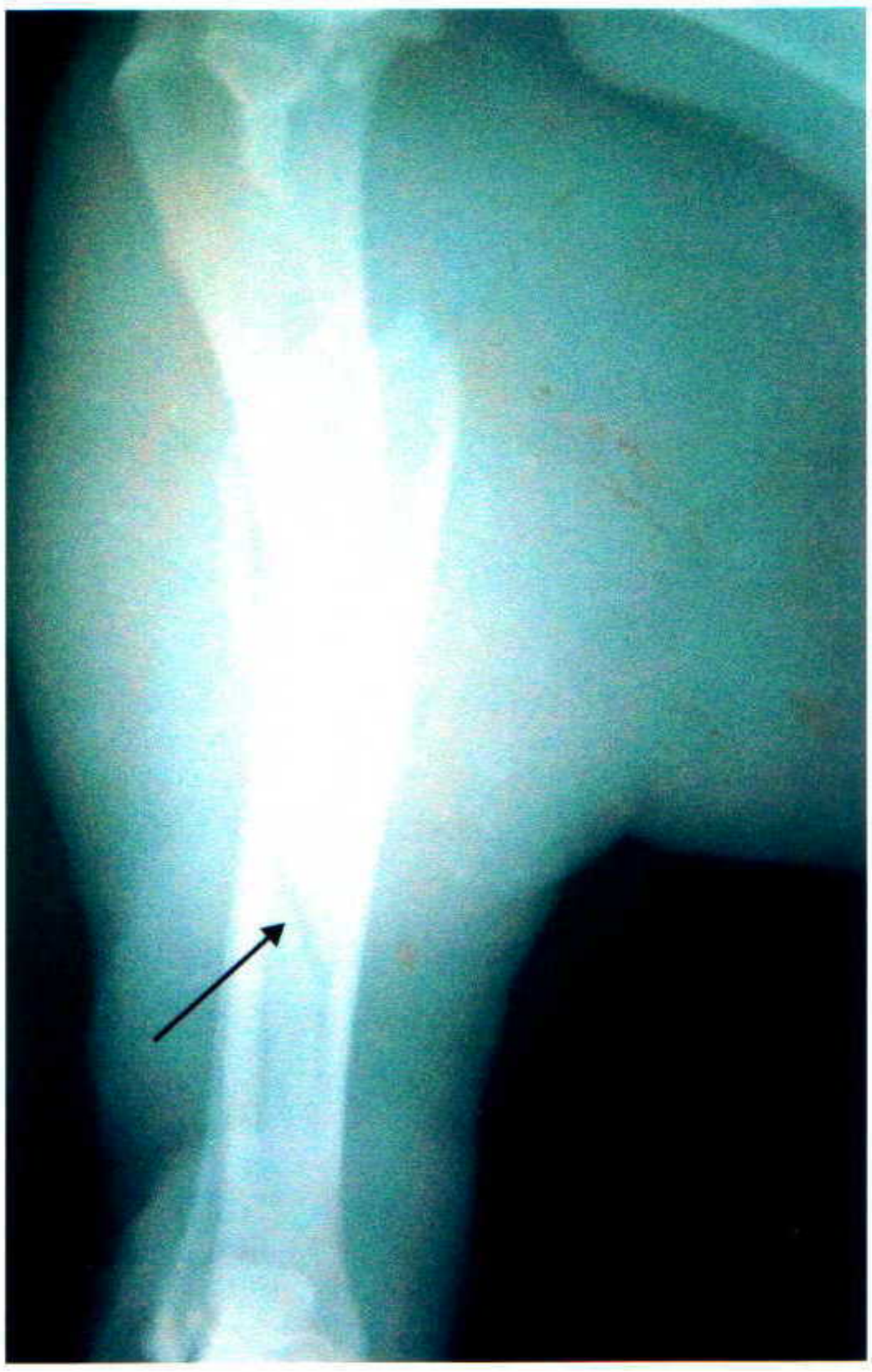


Fig. 13

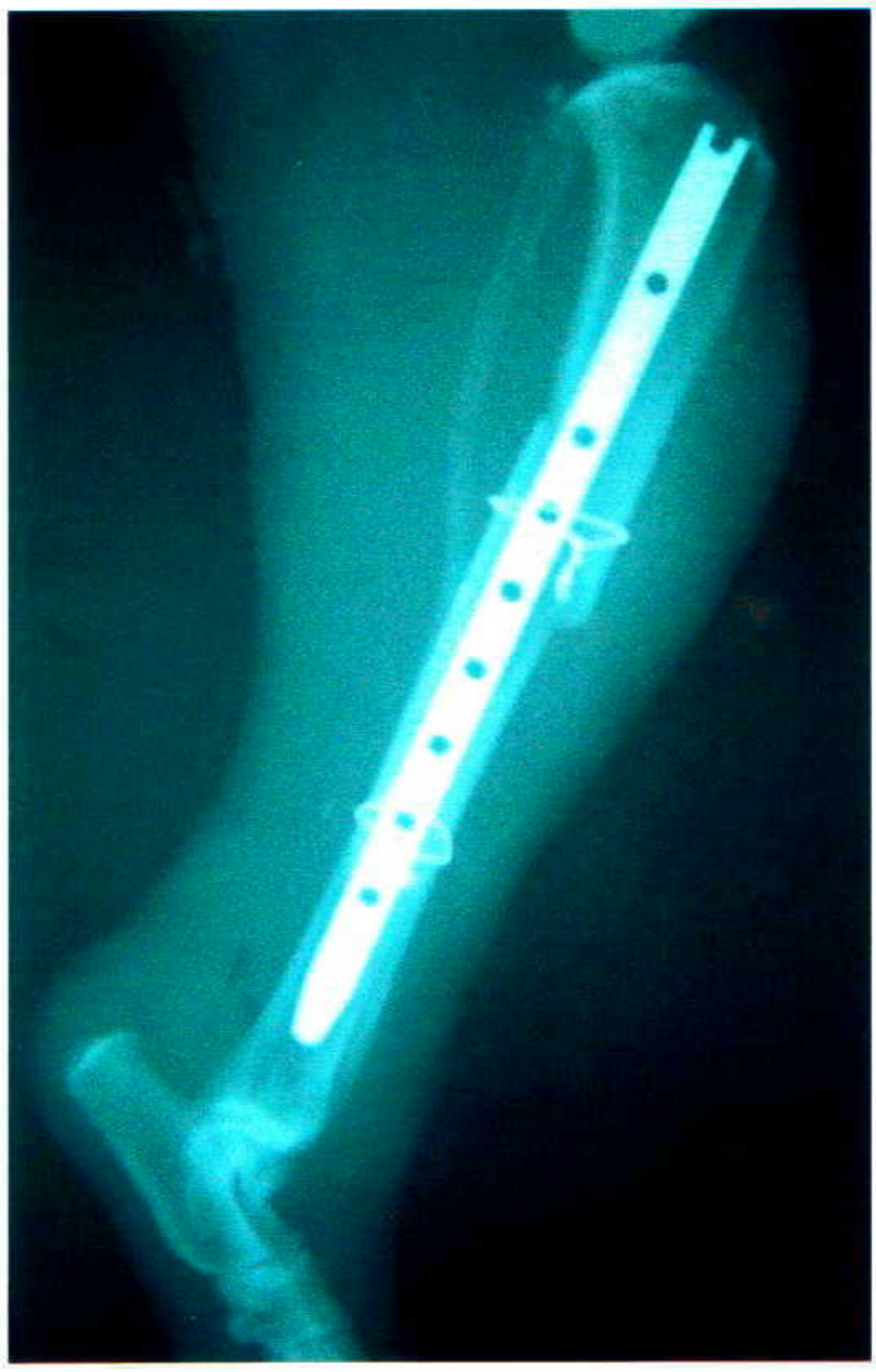


Fig. 14

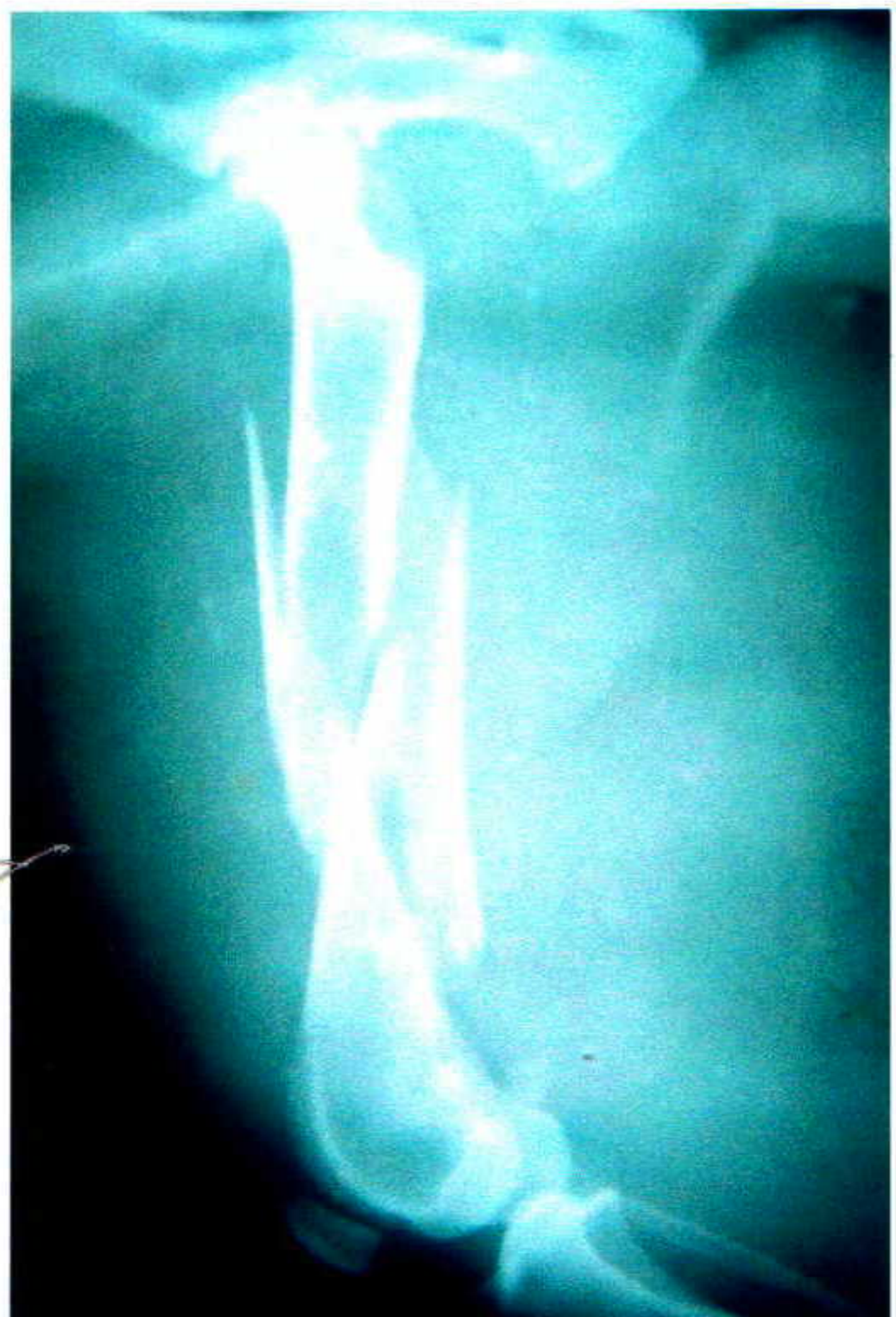


Fig. 15

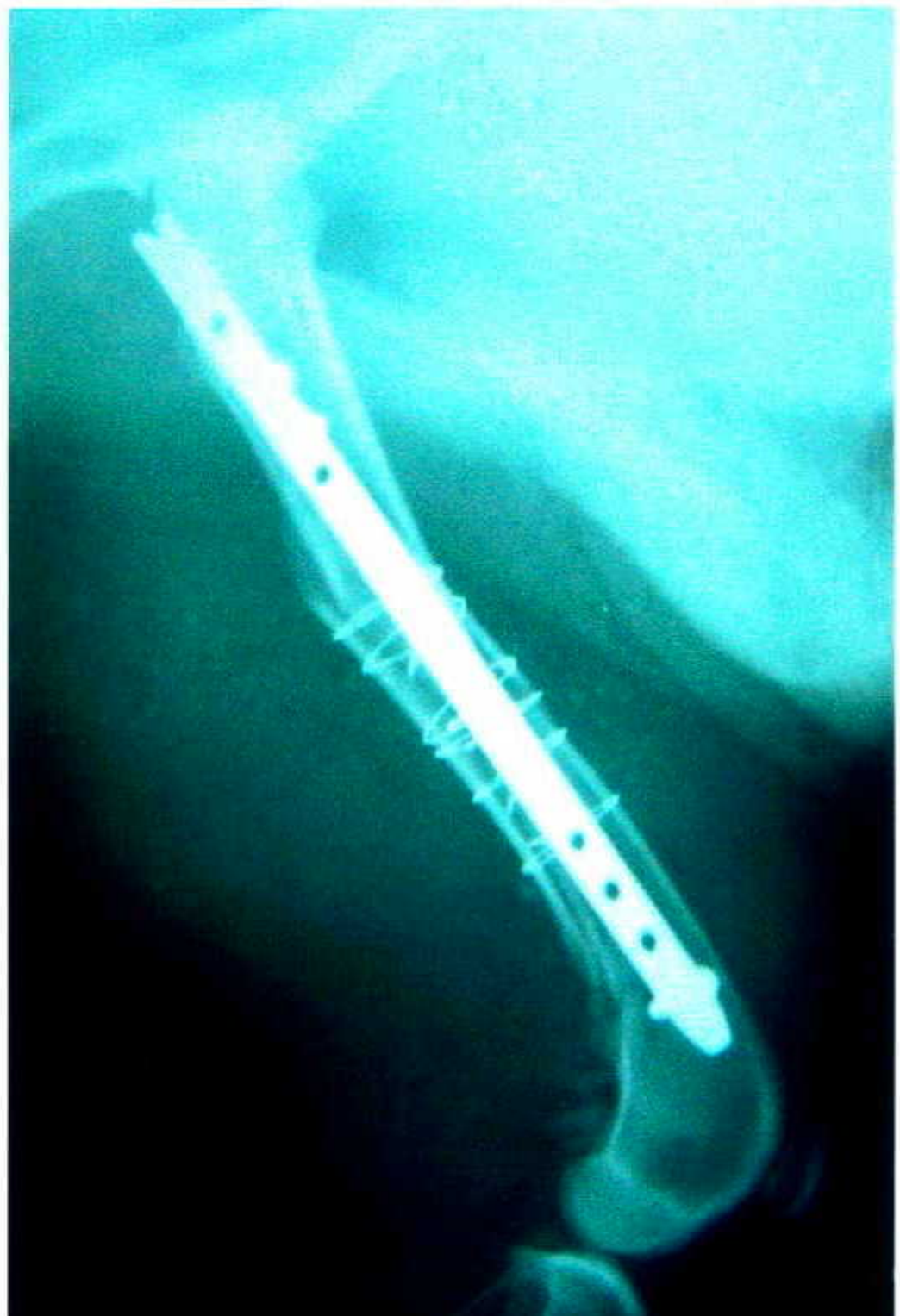


Fig. 16

4.5.1.2 Group II

In all dogs of this group, immediate post operative radiograph revealed adequate fracture reduction. In dog 1, subtrochantric fracture was repaired satisfactorily. The proximal screw and proximal distal screw was very close to the fracture site (Fig 17, 18). The reduction was suitable. In dog 2, immediate post operative radiograph revealed fracture line (Fig 19, 20). This was due to the fact that oblique or spiral mid shaft humeral fractures was always difficult to reduce. In dog 6, slight cranial displacement of proximal fracture fragment was evident in immediate post operative radiograph (Fig 21, 22). In dog 9, fracture fragments were not in contact at cranial aspect due to bone loss present at the site (Fig 23, 24). In dog 11, bilateral femur fracture was treated satisfactorily (Fig 25, 26, 27). However, the fracture fixation in left femur failed due to jump from height on second post operative day. The fracture created was more complex than the earlier simple oblique femur fracture (Fig 28) and was satisfactorily stabilized using static intramedullary IL nail and 4 full cerclage wires (Fig 29). In dog 12, the bilateral fracture (Fig 30, 31) was reduced with acceptable reduction in both the limbs (Fig 32). The results suggested that use of more than one transcortical screws in distal fragment were also able to provide adequate stability to implant immediate post operatively in wide range of fractures.

Fig 17: Pre operative radiograph (craniocaudal view), proximal femur fracture subtrochanteric zone (G-II, D-1).

Fig 18: Immediate post operative radiograph (craniocaudal view), showing fixation of fracture fragments with static intramedullary IL nailing, the proximal and proximal of the distal screws very close to fracture line (G-II, D-1).

Fig 19: Pre operative radiograph (lateral view), midshaft slight oblique humerus fracture (G-II, D-2).

Fig 20: Immediate post operative radiograph (lateral view), showing fixation of fracture fragments with static intramedullary IL nailing; fracture line is evident (G-II, D-2).

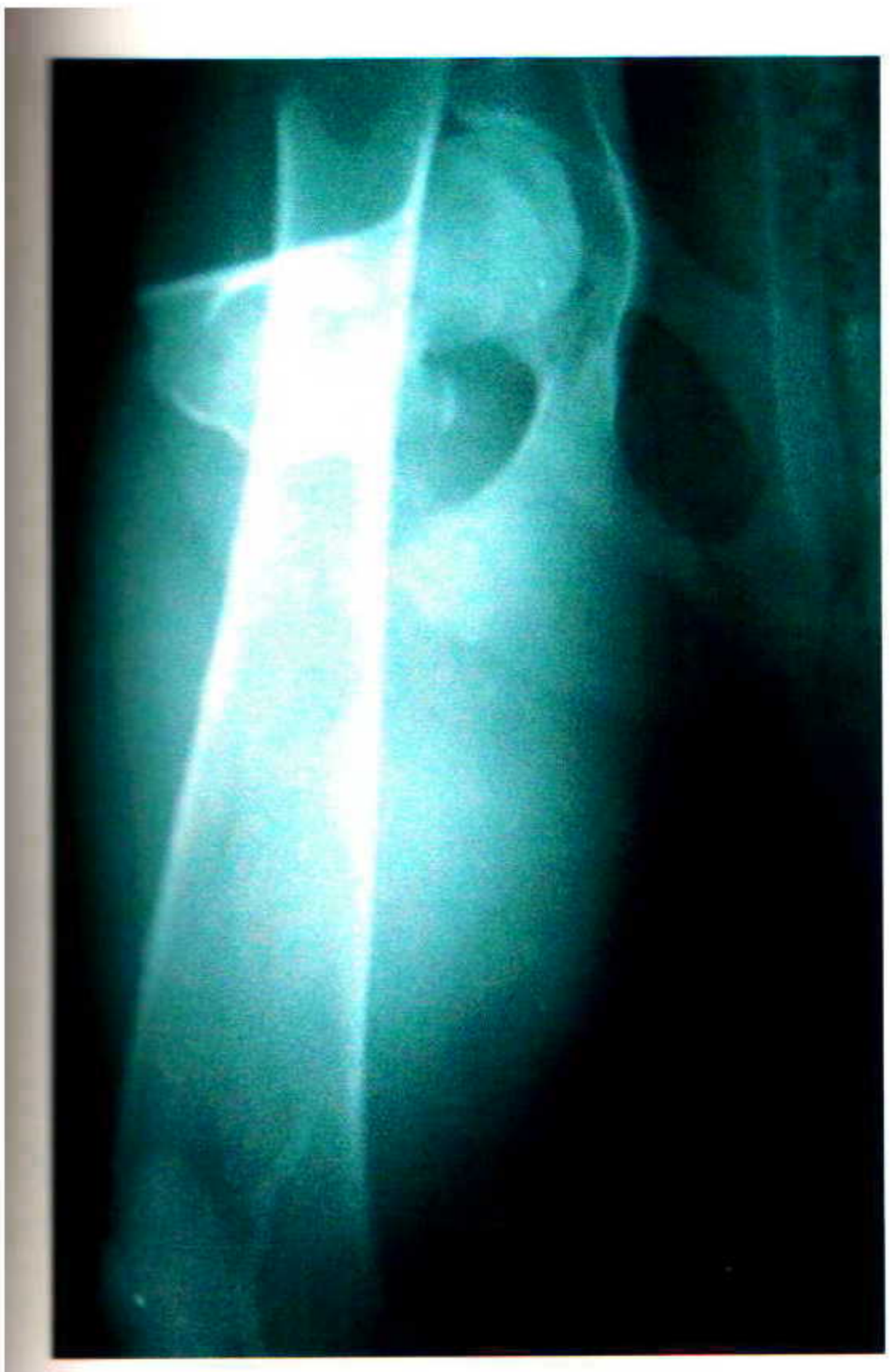


Fig. 17

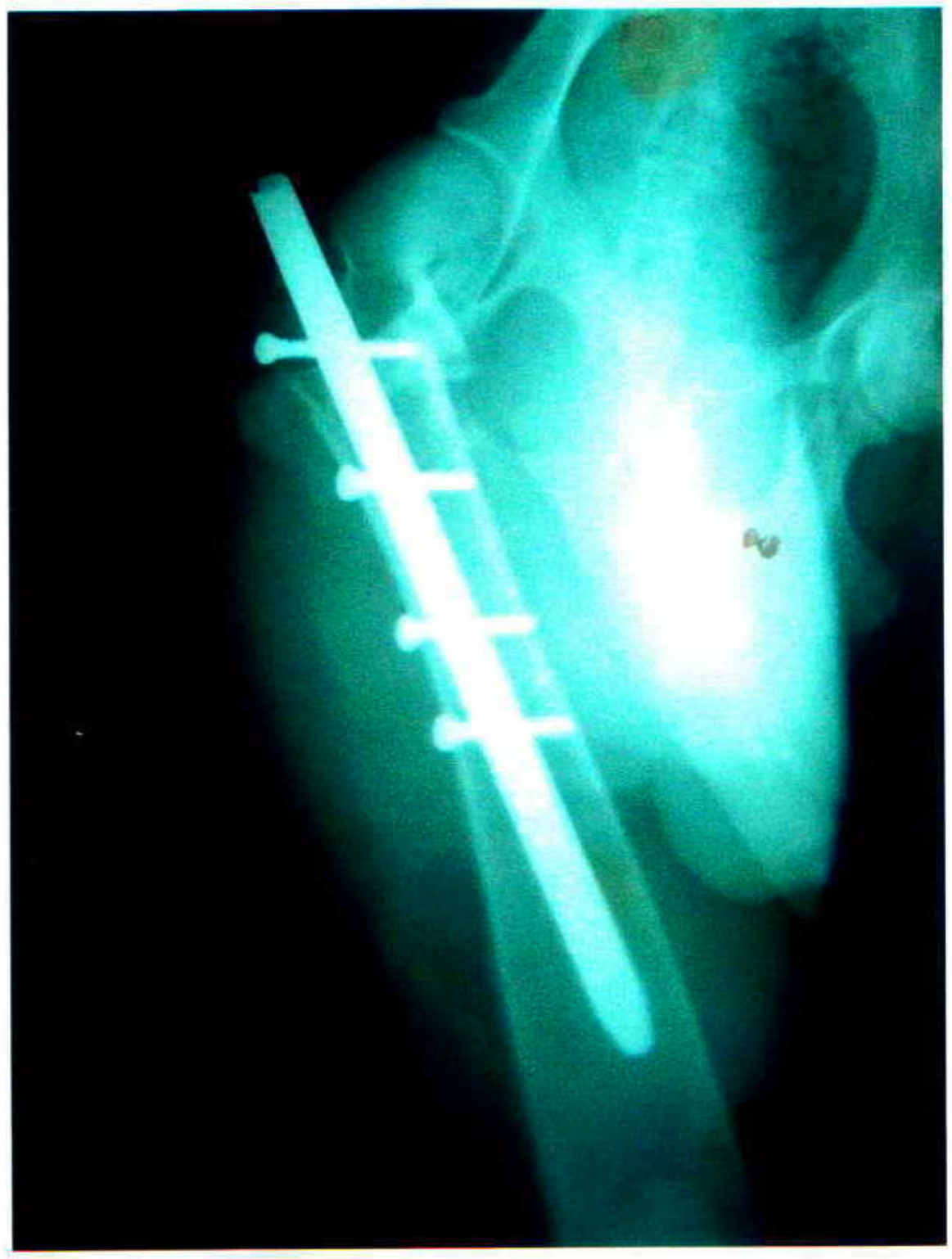


Fig. 18

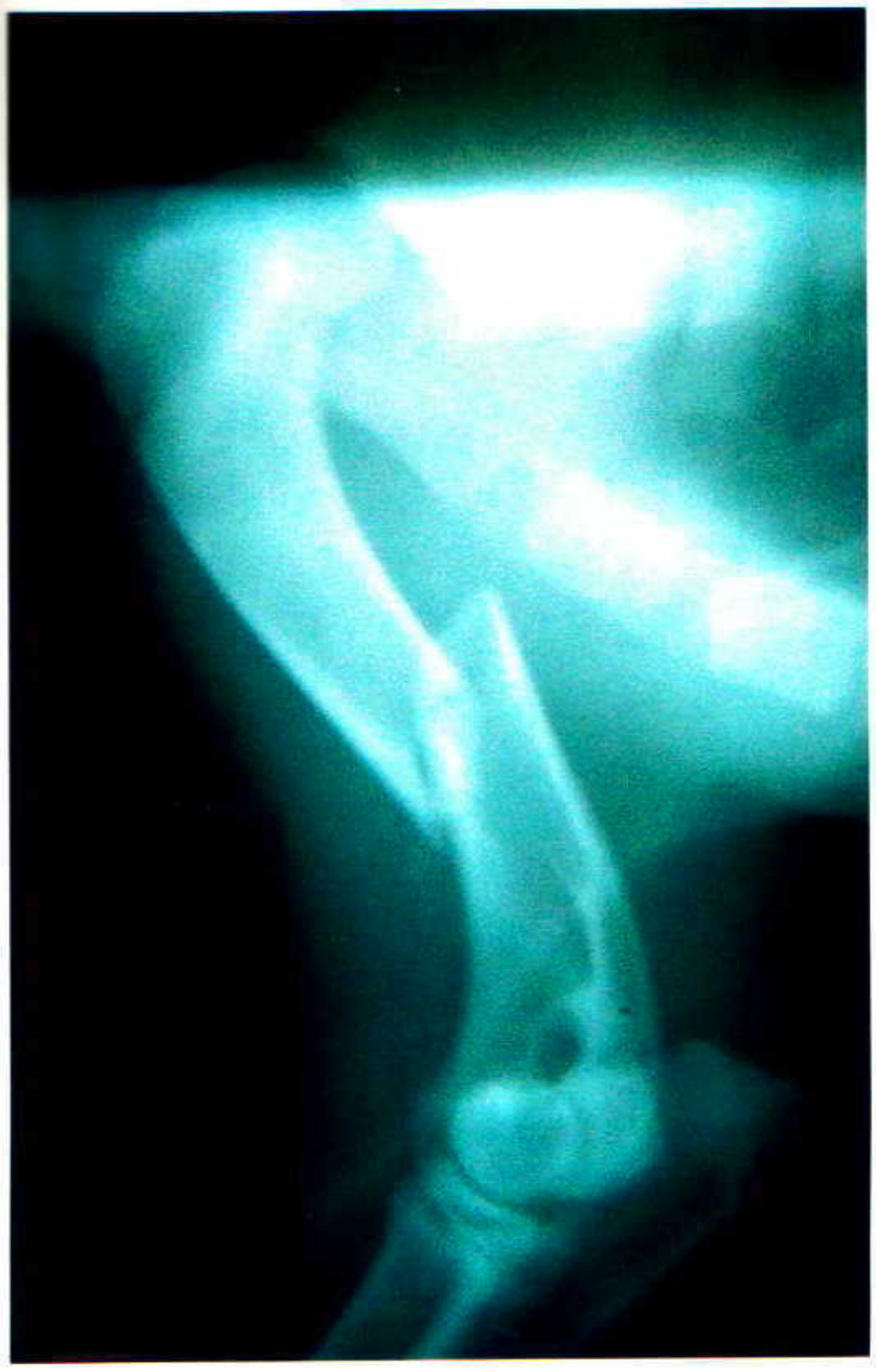


Fig. 19

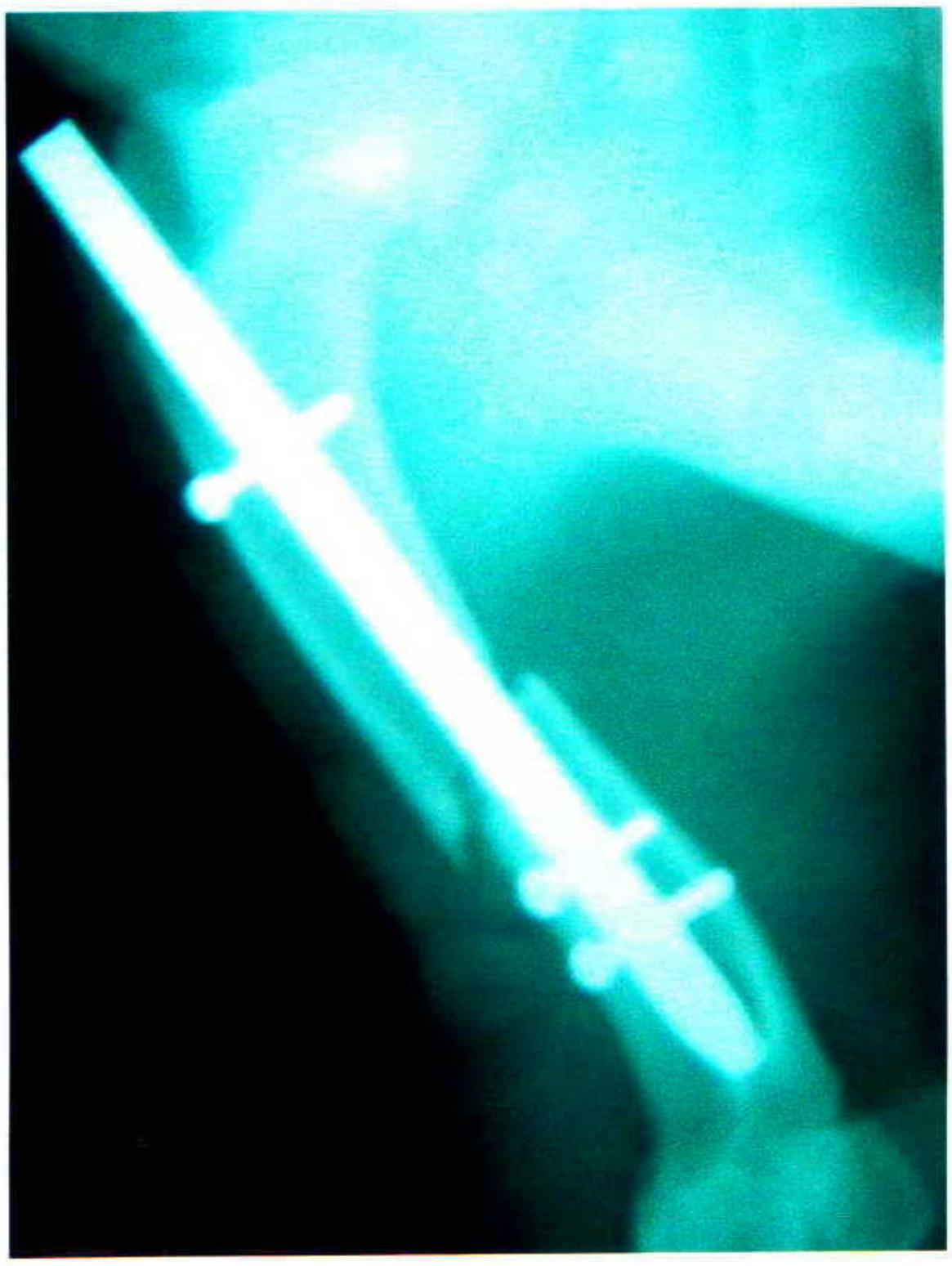


Fig. 20

Fig 21: Pre operative radiograph (lateral view), proximal slight oblique femur fracture (G-II, D-6).

Fig 22: Immediate post operative radiograph (lateral view), showing fracture fixation with slight cranial displacement of proximal fragment (arrow) (G-II, D-7).

Fig 23: Pre operative radiograph (lateral view), distal transverse femur fracture (G-II, D-9).

Fig 24: Immediate post operative radiograph (lateral view), showing fracture fixation with slight gap at the fracture site due to bone loss at the cranial aspect of the bone (arrow) (G-II, D-9).

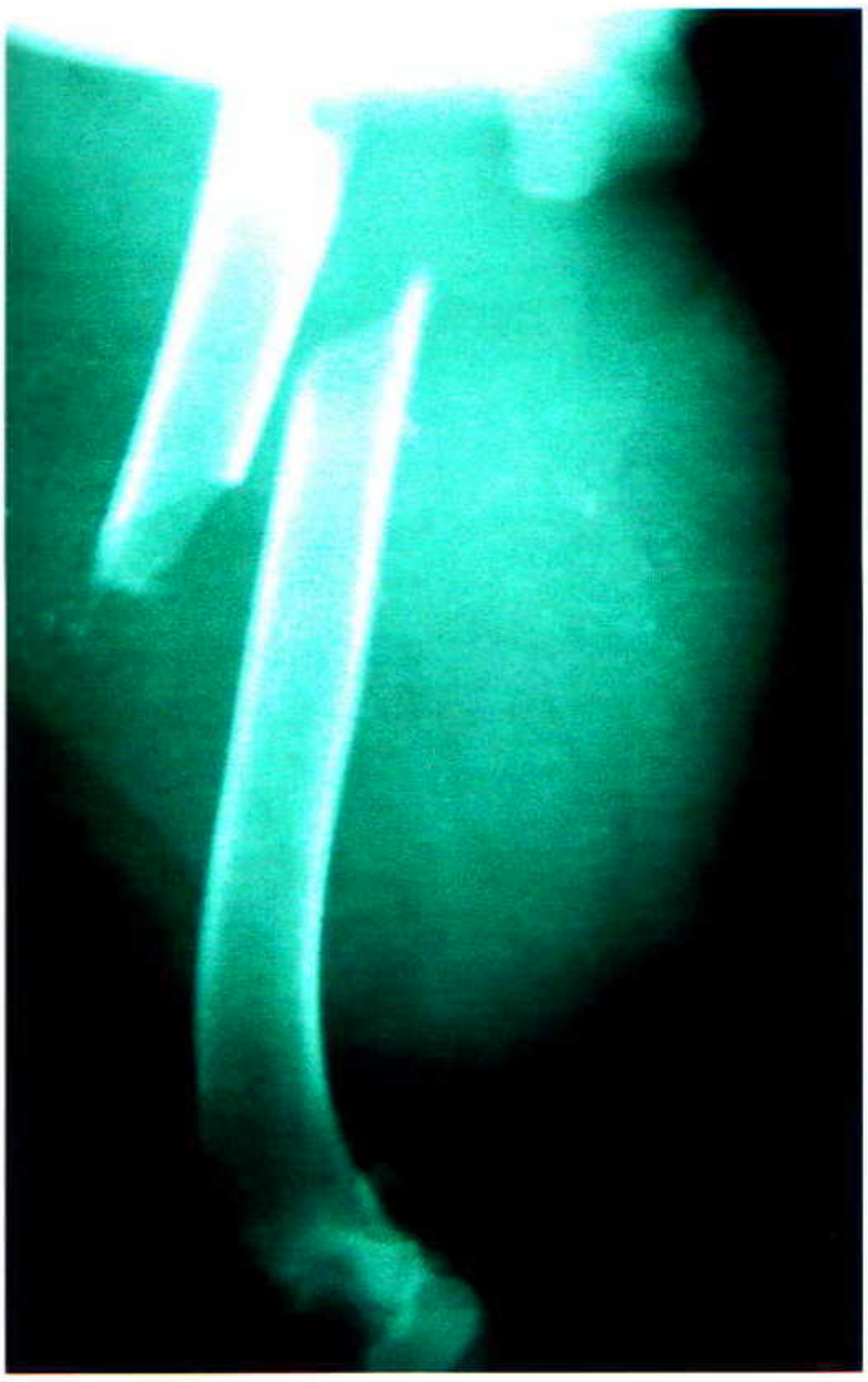


Fig. 21

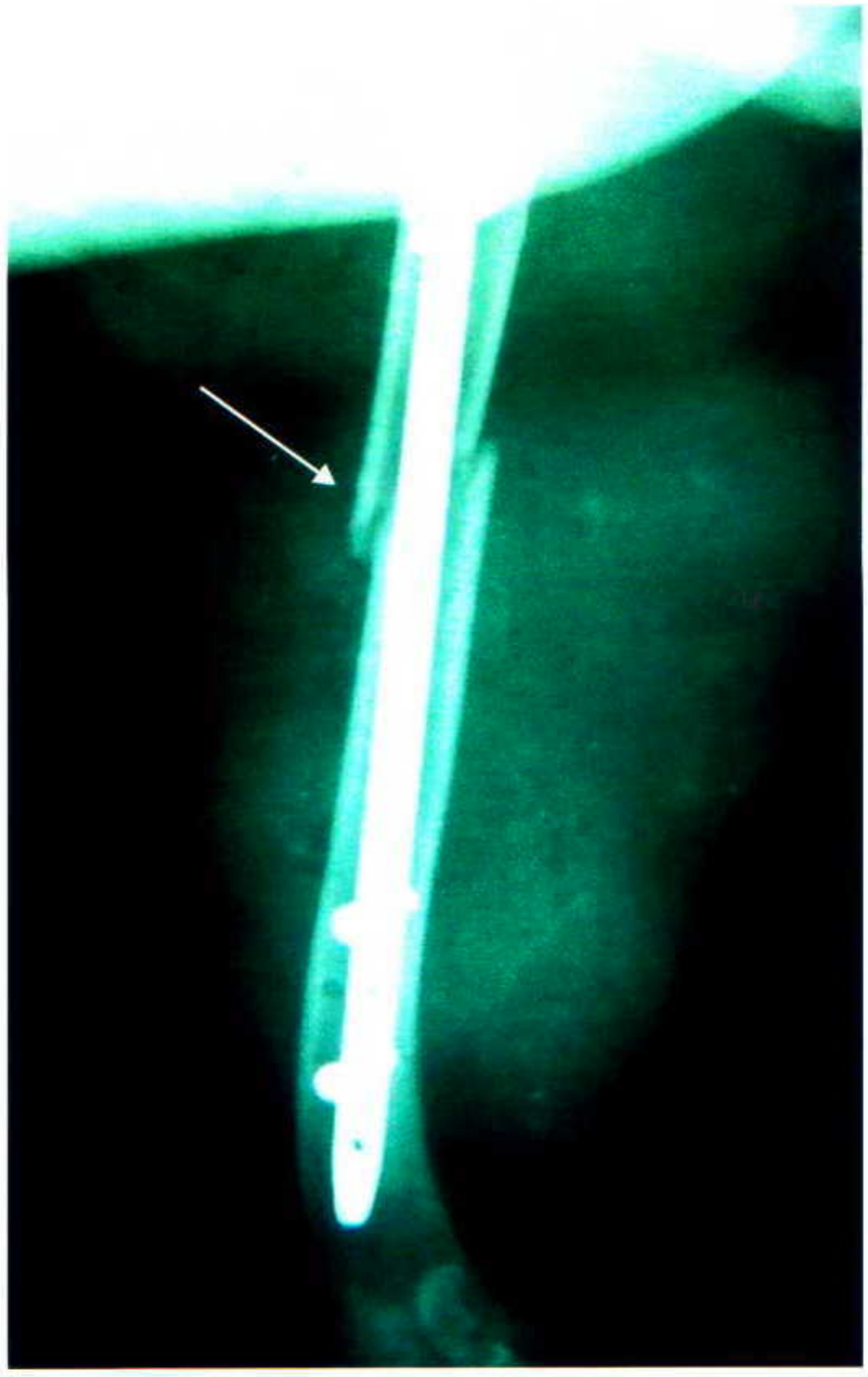


Fig. 22

Fig. 23

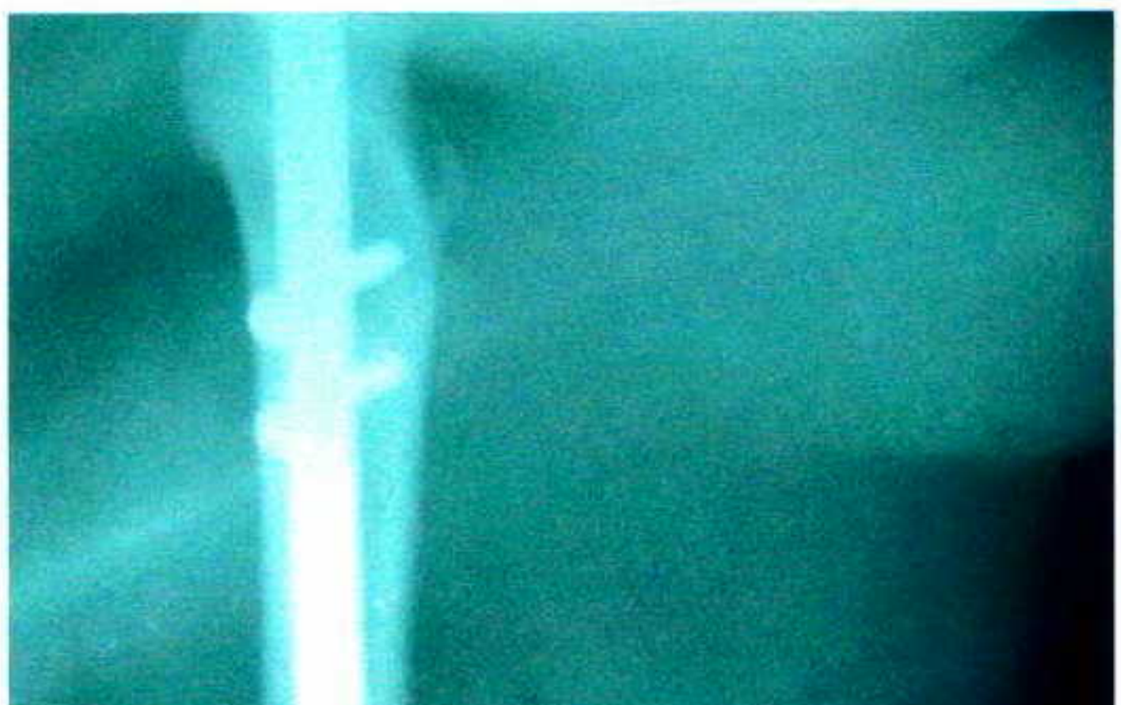


Fig. 24

Fig 25: Pre operative radiograph (lateral view), with midshaft slight oblique femur (Le limb) fracture with large reducible chip (G-II- D11).

Fig 26: Pre operative radiograph (lateral view), with midshaft slight oblique femur (Rt limb) fracture with small irreducible chip (G-II- D11).

Fig 27: Immediate post operative radiograph (lateral view), showing fracture fixation in right limb with static intramedullary IL nailing (G-II, D-11).

Fig 28: 2nd day post operative radiograph (craniocaudal view), showing fracture fixation failure in left limb with conversion of slight oblique fracture into a complex segmental fracture (arrow), right limb implant is stable (G-II, D-11).

Fig 29: Immediate post operative radiograph (lateral view), showing fracture fixation with static intramedullary Il nailing and 4 full cerclage wires in the left limb after initial fracture fixation failure (G-II, D-11).

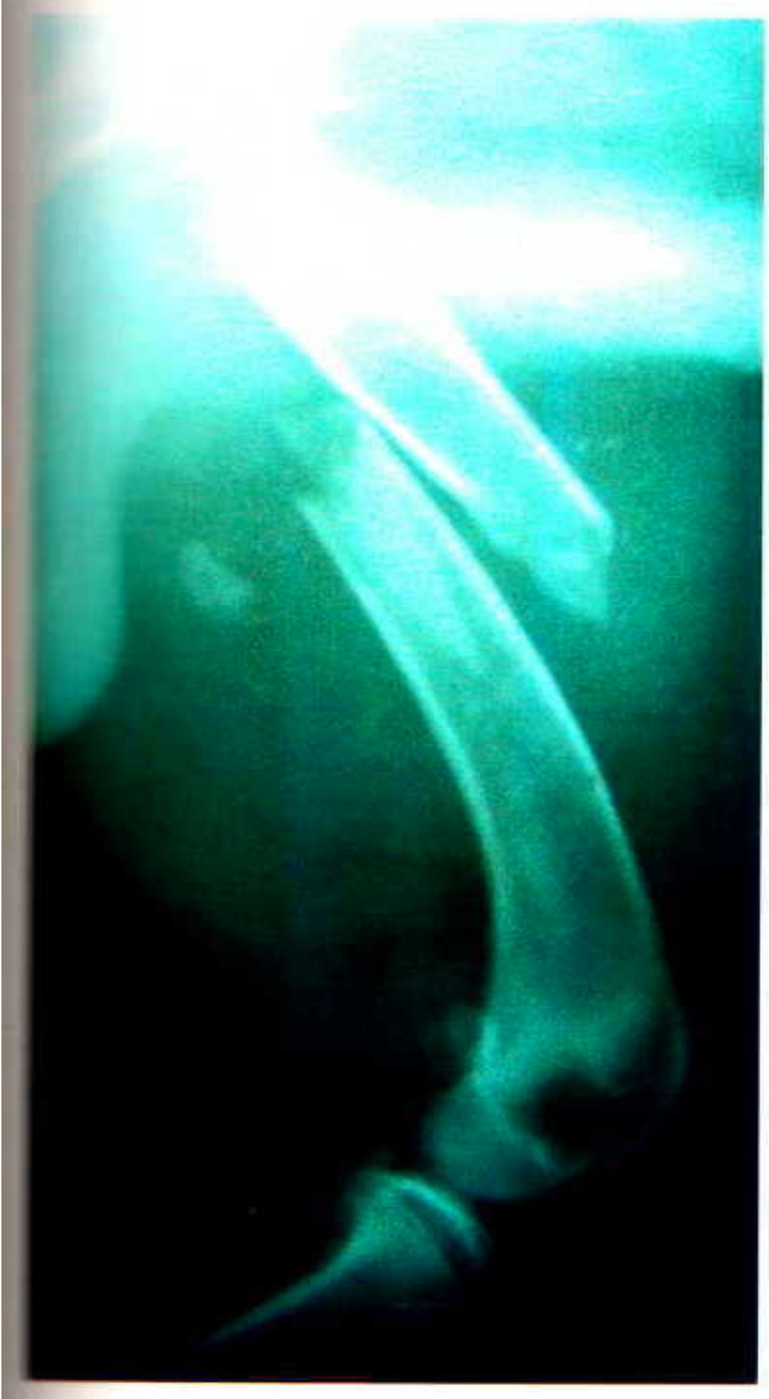


Fig. 25

Fig. 26

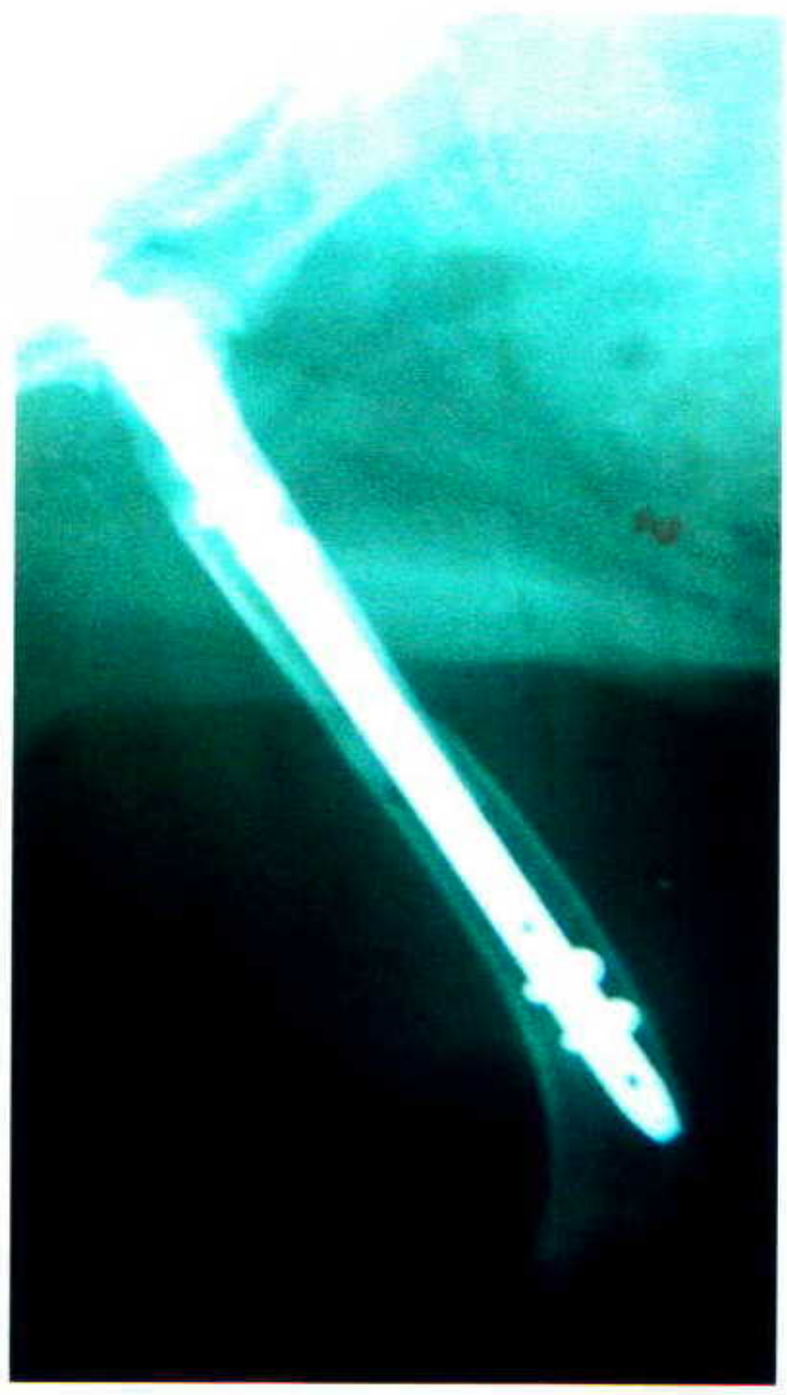


Fig. 27

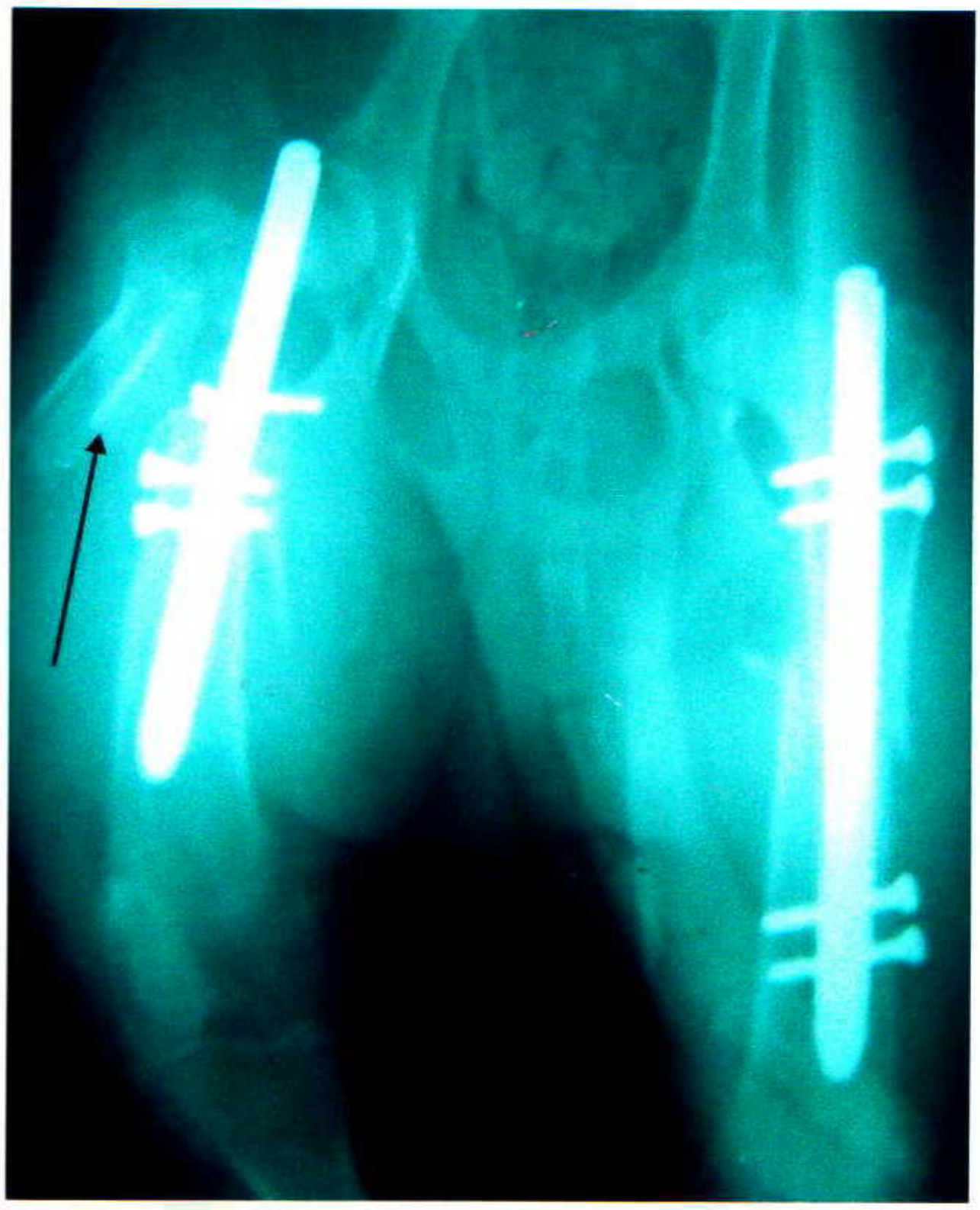


Fig. 28

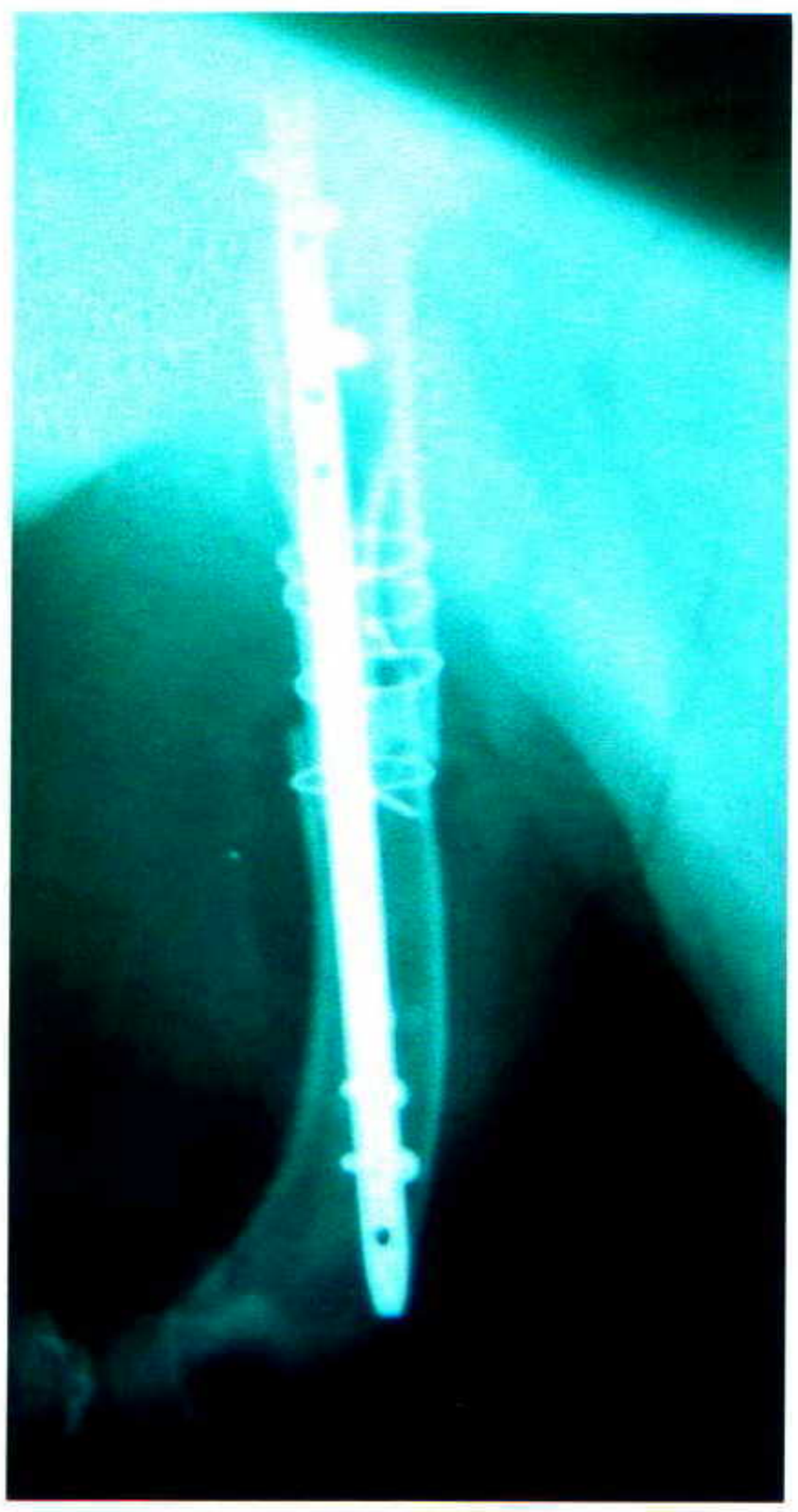


Fig. 29

Fig 30: Pre operative radiograph (craniocaudal view), with bilateral femur fracture (Left oblique midshaft, Right segmental fracture) (G-II, D-12).

Fig 31: Immediate post operative radiograph (lateral view), showing fracture fixation with static intramedullary IL nailing and 3 full cerclage wires in the right limb (G-II, D-12).

Fig 32: Immediate post operative radiograph (lateral view), showing fracture fixation with static intramedullary IL nailing in the left limb (G-II, D-12).

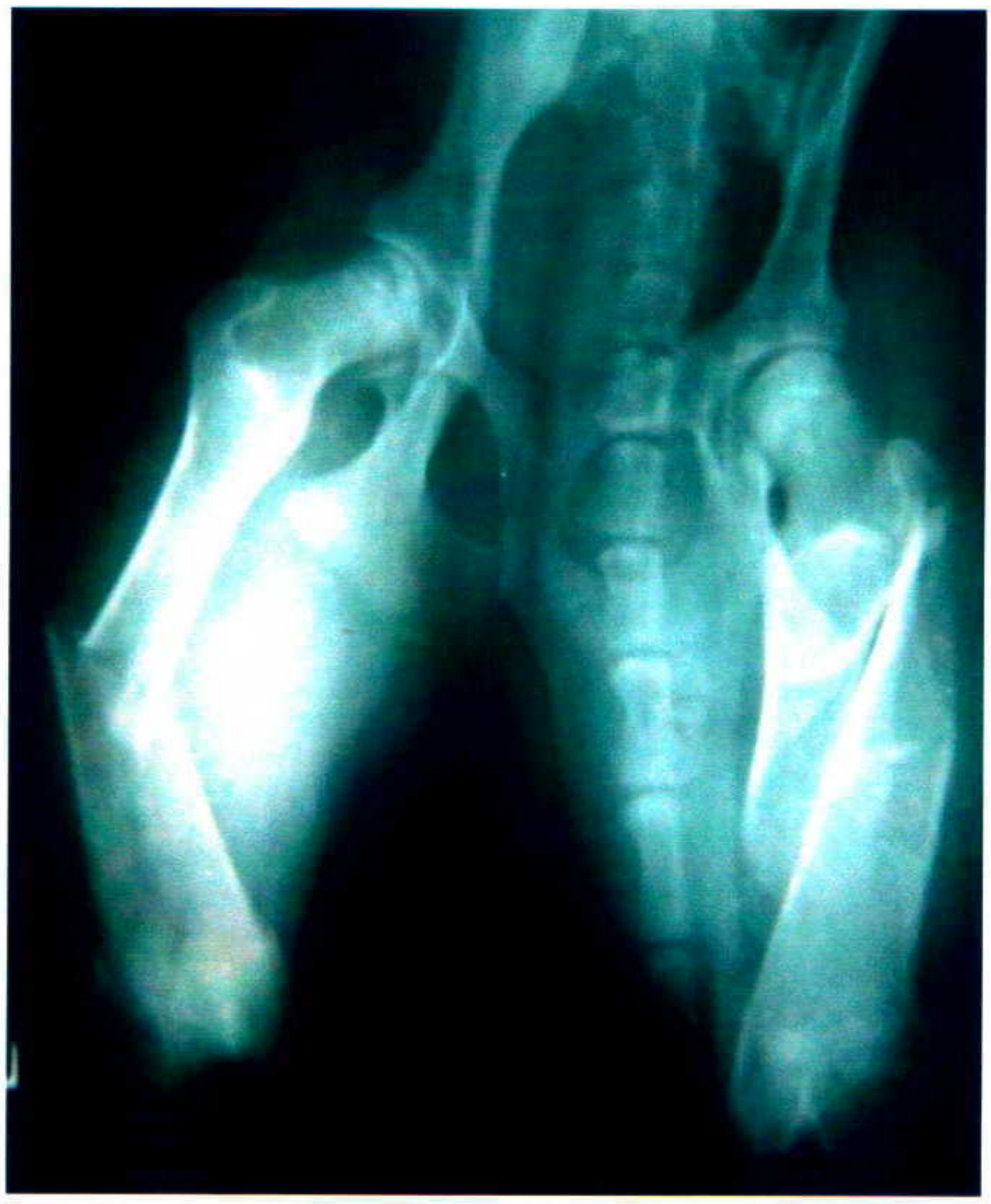


Fig. 30

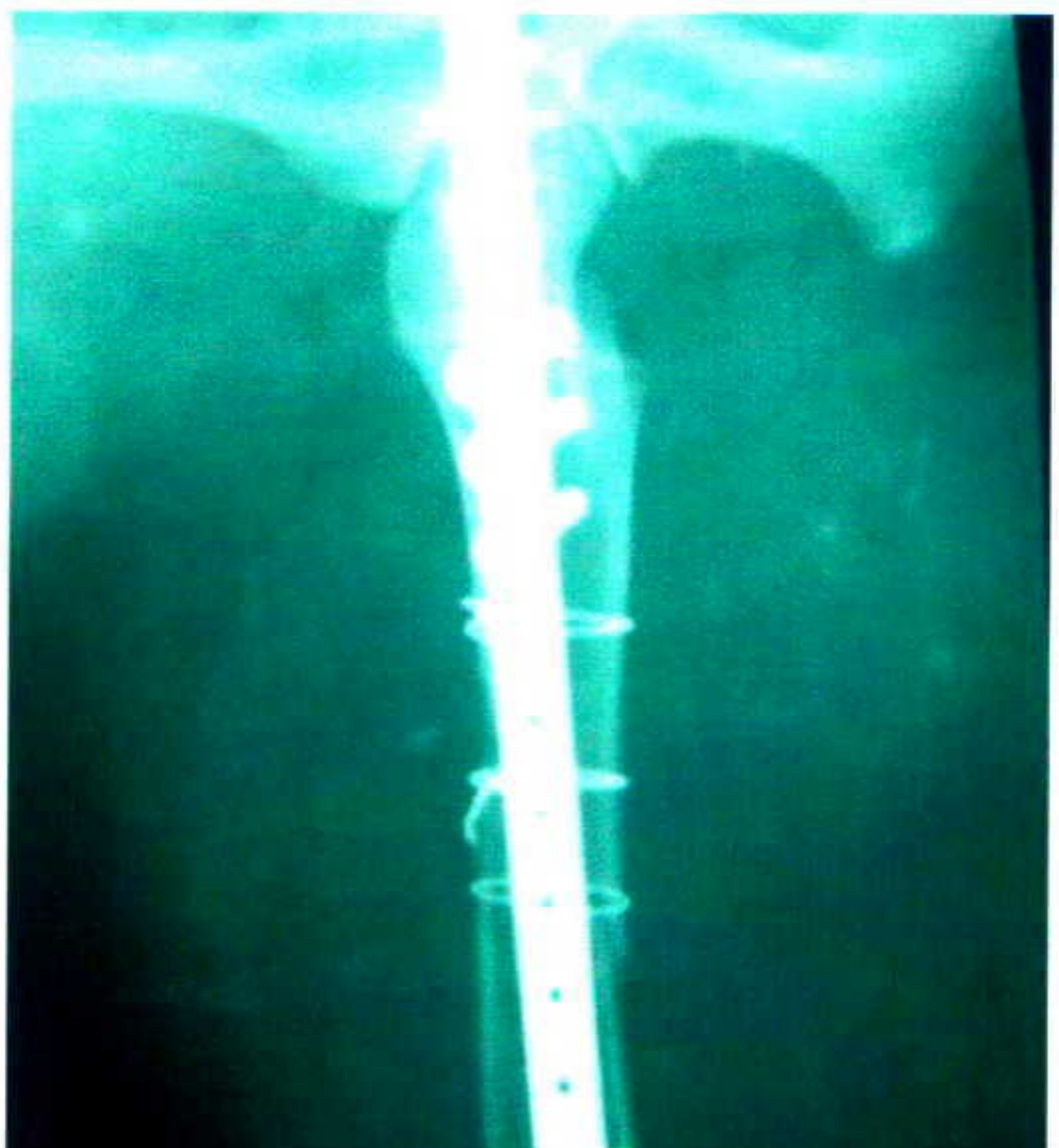


Fig. 31

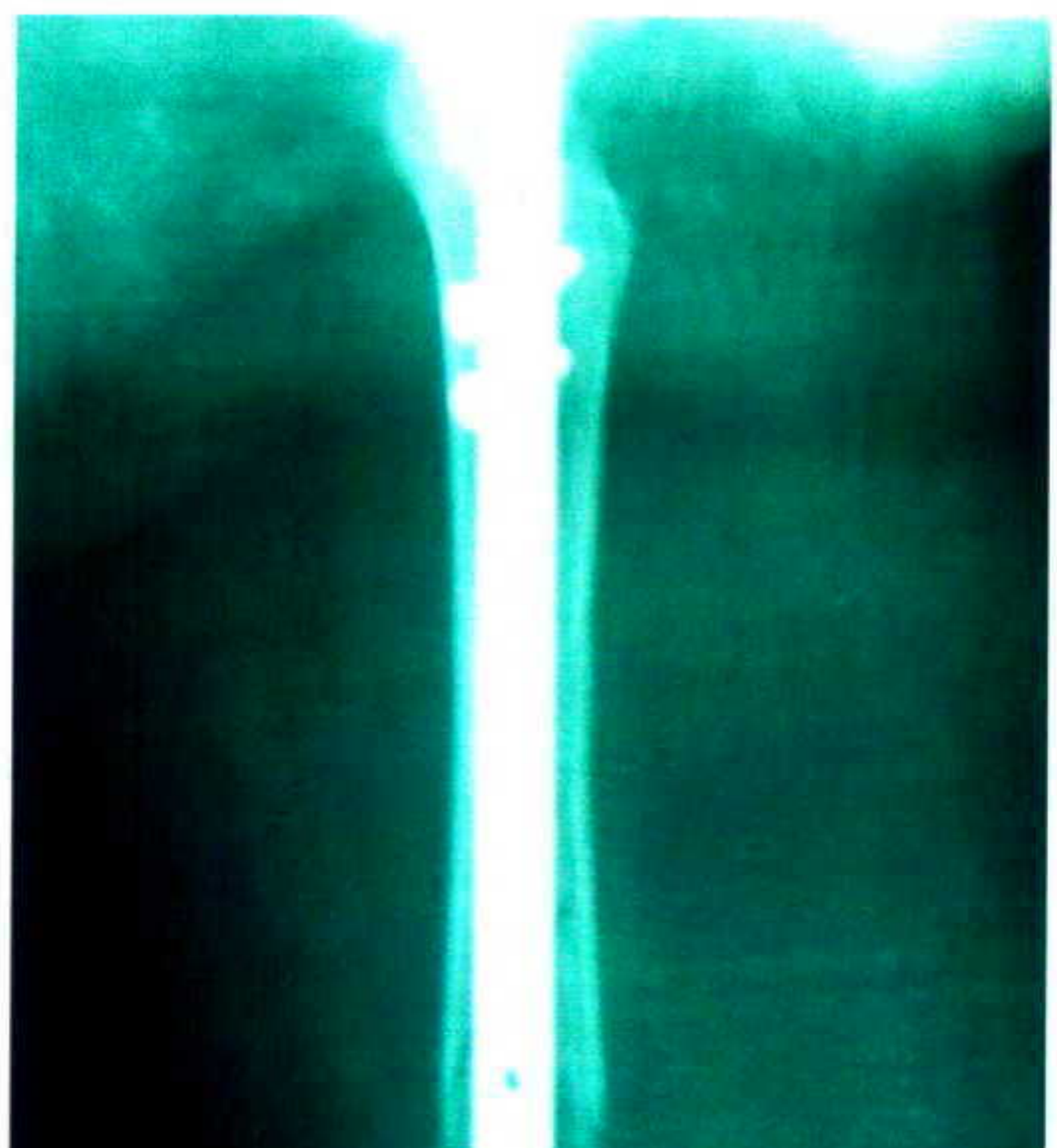


Fig. 32

4.5.2 Fracture Healing

4.5.2.1: 10th-15th day post operative

Group I

In group I, in all the cases, sign of periosteal reaction was evident from 10th -15th day post operative radiographs (Fig 33, 34).

Group II

In group II, in almost all the cases signs of periosteal reaction was evident at this stage (Fig 35, 36, 37).

Periosteal reaction was evident in both the groups however fracture line was also evident in few cases at this stage.

4.5.2.2: 30-90 days post operative

Group I

Excessive periosteal bridging callus was evident on radiographs. In dog 1, with an oblique tibia fracture, bridging callus was evident which filled the gap at the fractures ends (Fig 38). Dog 2, with oblique mid shaft femur fracture also revealed signs of cortical continuity at this stage of radiograph. The irreducible chips that were evident on immediate post operative radiograph were now incorporated into the bridging callus (Fig 39). Dog 3 also showed the signs of

Fig 33: Periosteal reaction seen on fracture site 15th post operative day (lateral view) (arrow) (G-I, D-2).

Fig 34: Periosteal reaction seen on fracture site 15th post operative day (lateral view) (arrow) (G-I, D-7).

Fig 35: Periosteal reaction seen on fracture site 15th post operative day (lateral view) (arrow) (G-II, D-3).

Fig 36: Periosteal reaction seen on fracture site 15th post operative day (lateral view) (arrow) (G-I, D-5).

Fig 37: 15th post operative day radiograph with periosteal reaction seen on fracture site (lateral view) (arrow) (G-II, D-8).

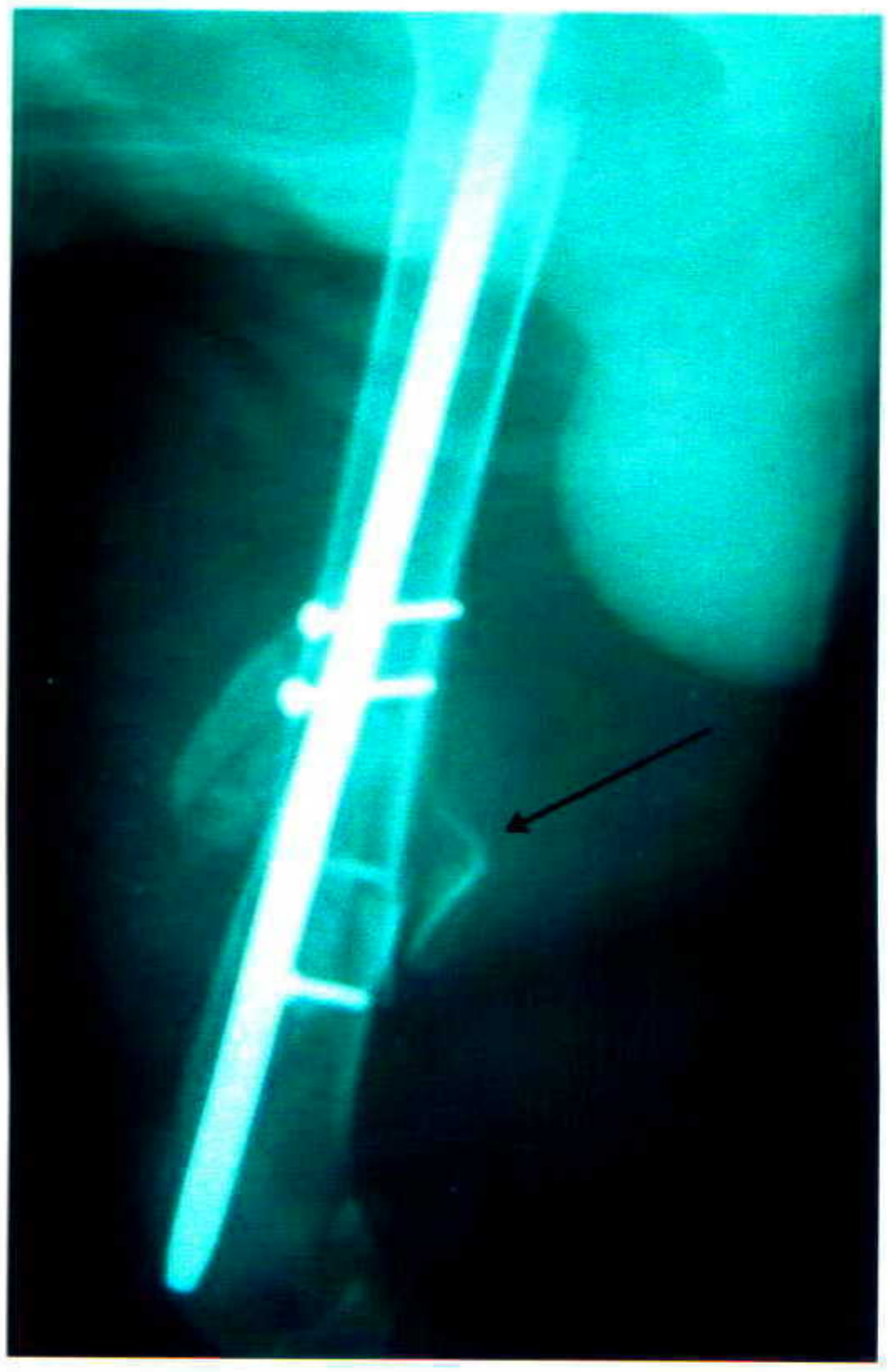


Fig. 33

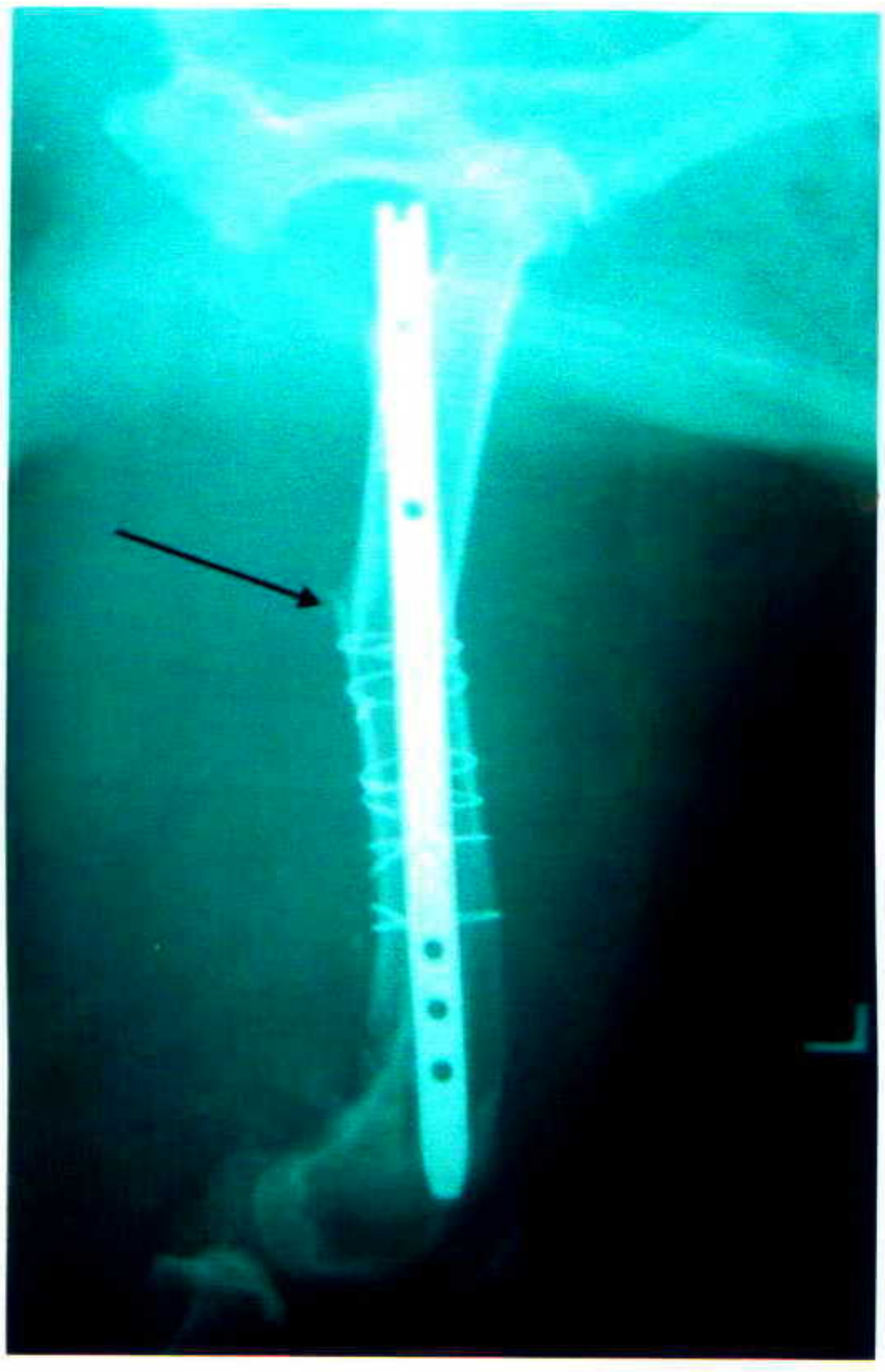


Fig. 34

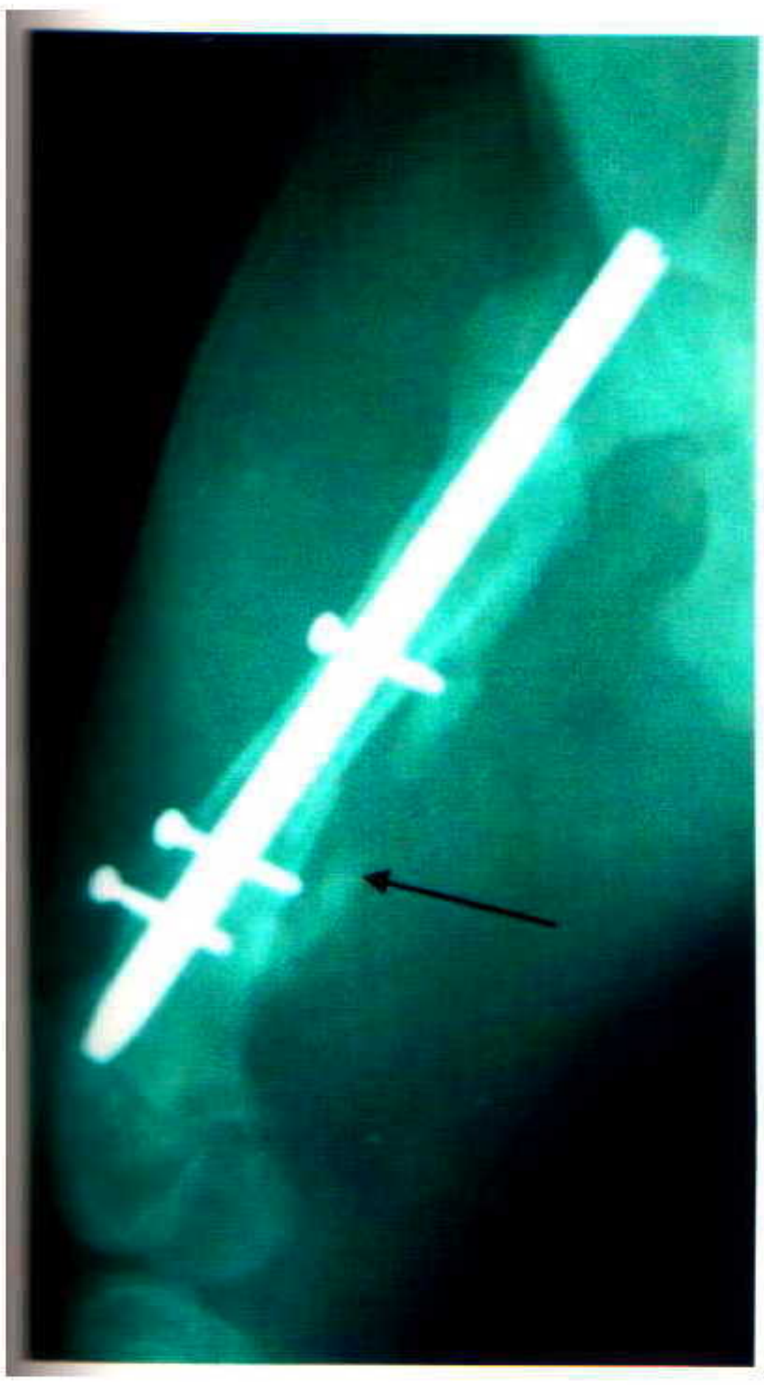


Fig. 35

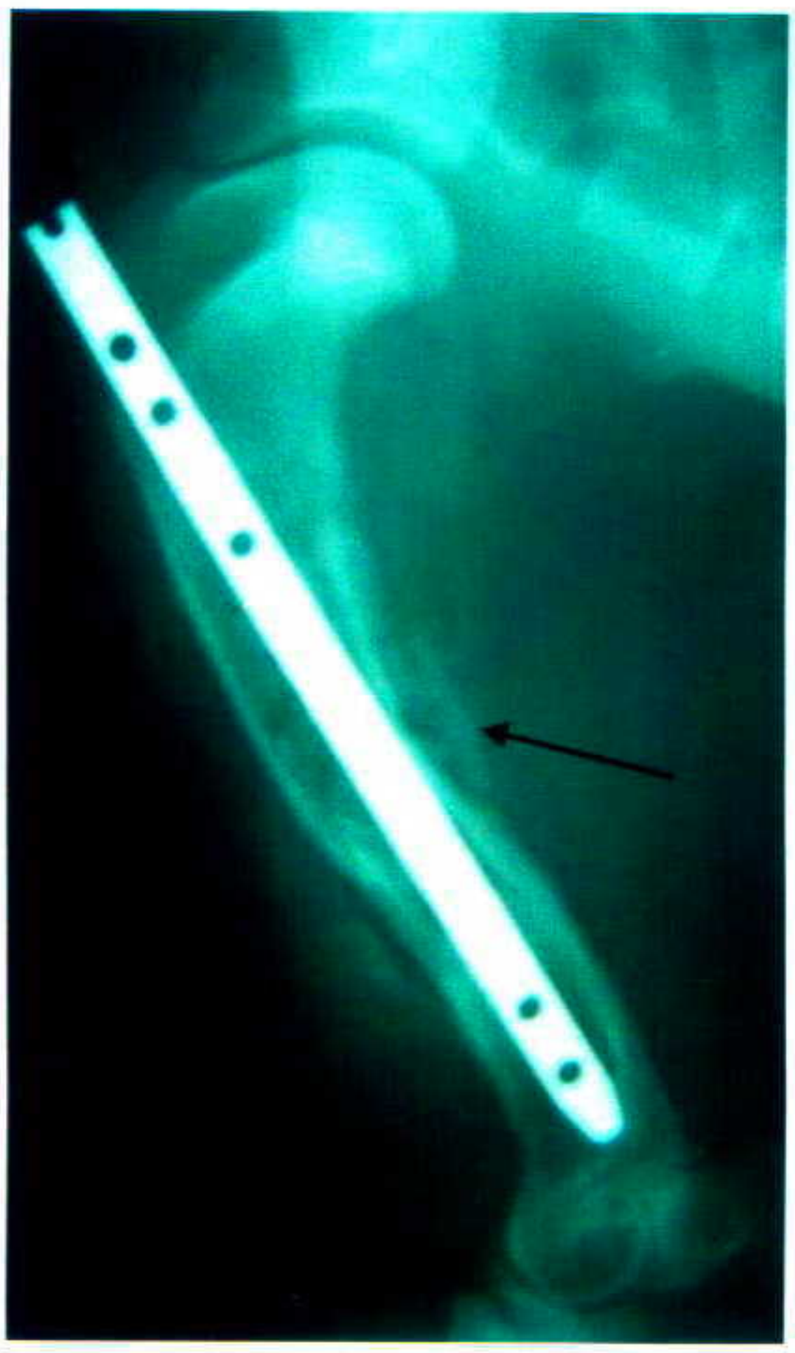


Fig. 36

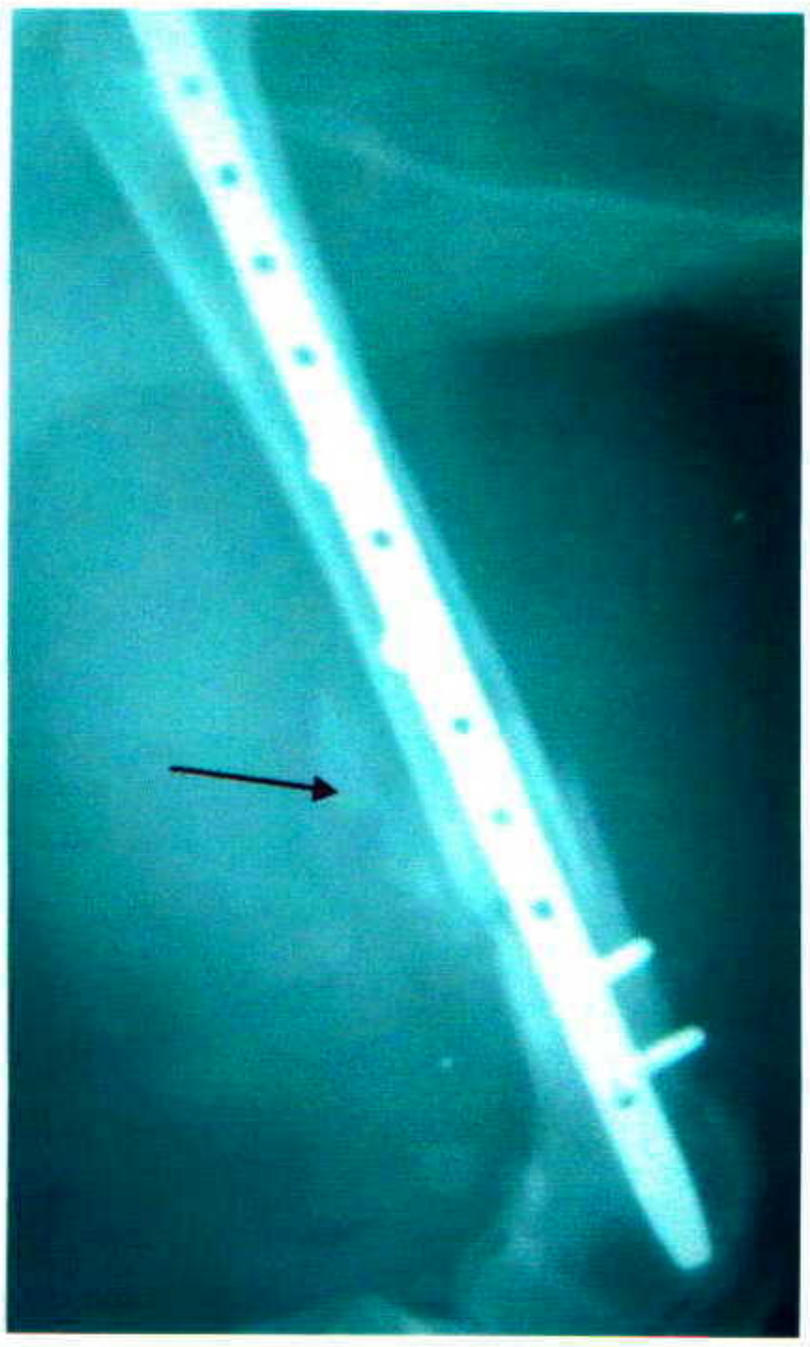


Fig. 37

Fig 38: 60th day post operative radiograph (lateral view) showing signs of cortical continuity (G-I, D-1).

Fig 39: 90th day post operative radiograph (lateral view) showing formation of bridging callus and signs of cortical continuity, the irreducible chips are incorporated into the healing callus (G-I, D-2).

Fig 40: 30th day post operative radiograph (lateral view) showing formation of bridging callus, cortical continuity also established at this stage (G-I, D-3).

Fig 41: 90th day post operative radiograph (lateral view) showing signs of delayed union with fracture line still evident on the cranial aspect of fracture site.(G-I, D-4).

Fig 42: 90th day post operative radiograph (craniocaudal view) showing formation of cortical continuity of the fractured bone (G-I, D-6).

Fig 43: 40th day post operative radiograph (lateral view) showing formation of bridging callus, signs of cortical continuity at places also evident (G-I, D-7)

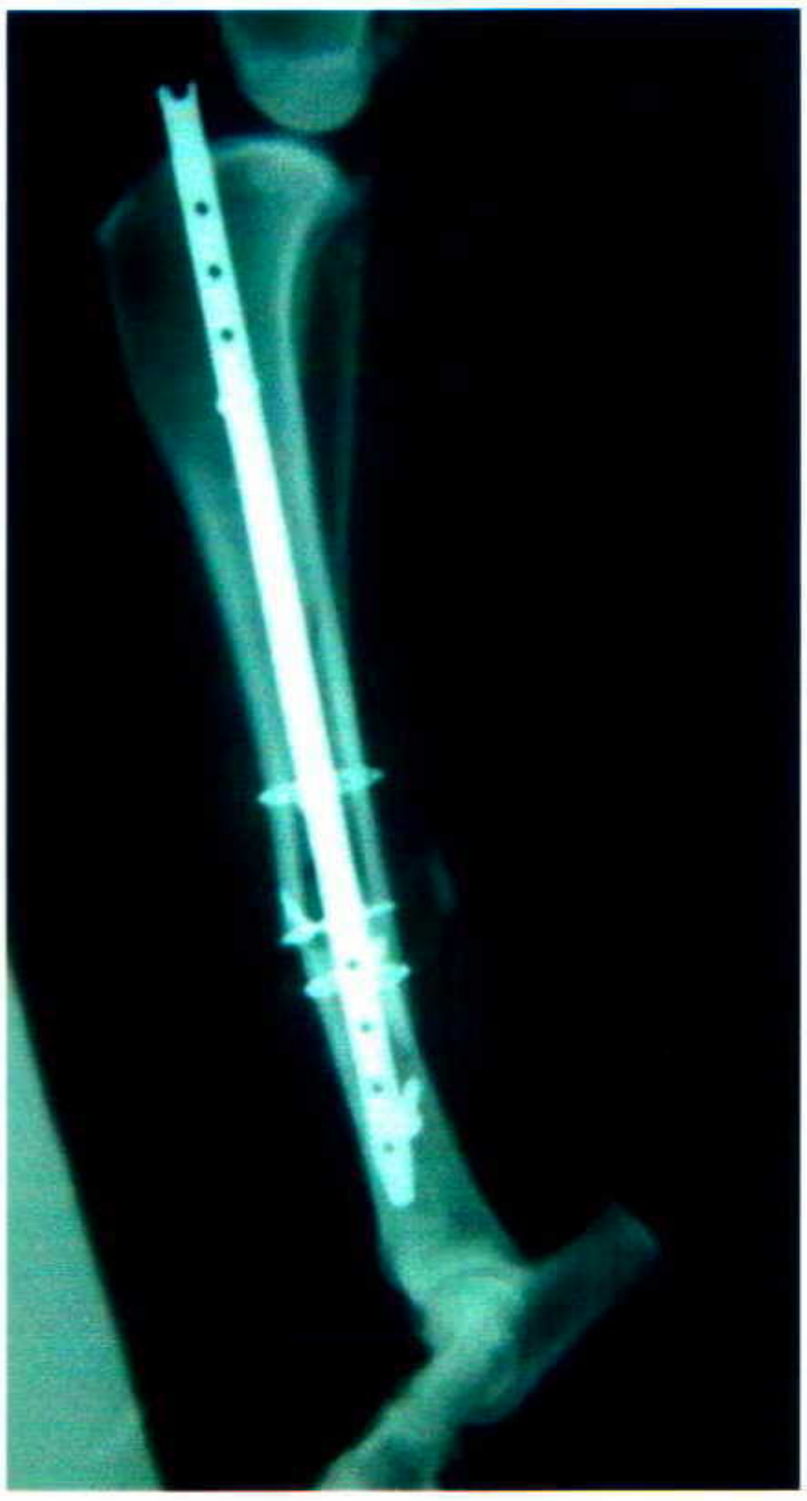


Fig. 38

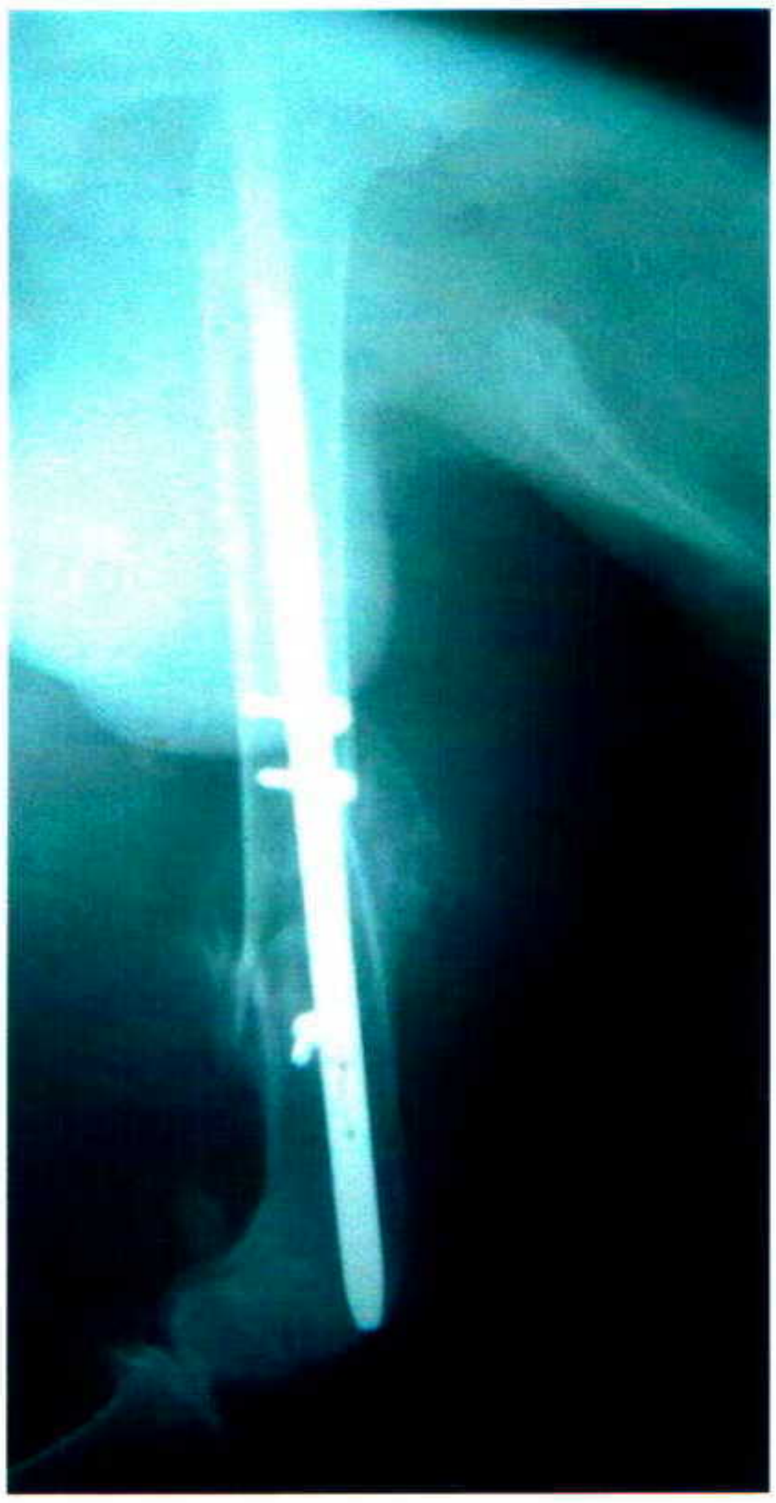


Fig. 39

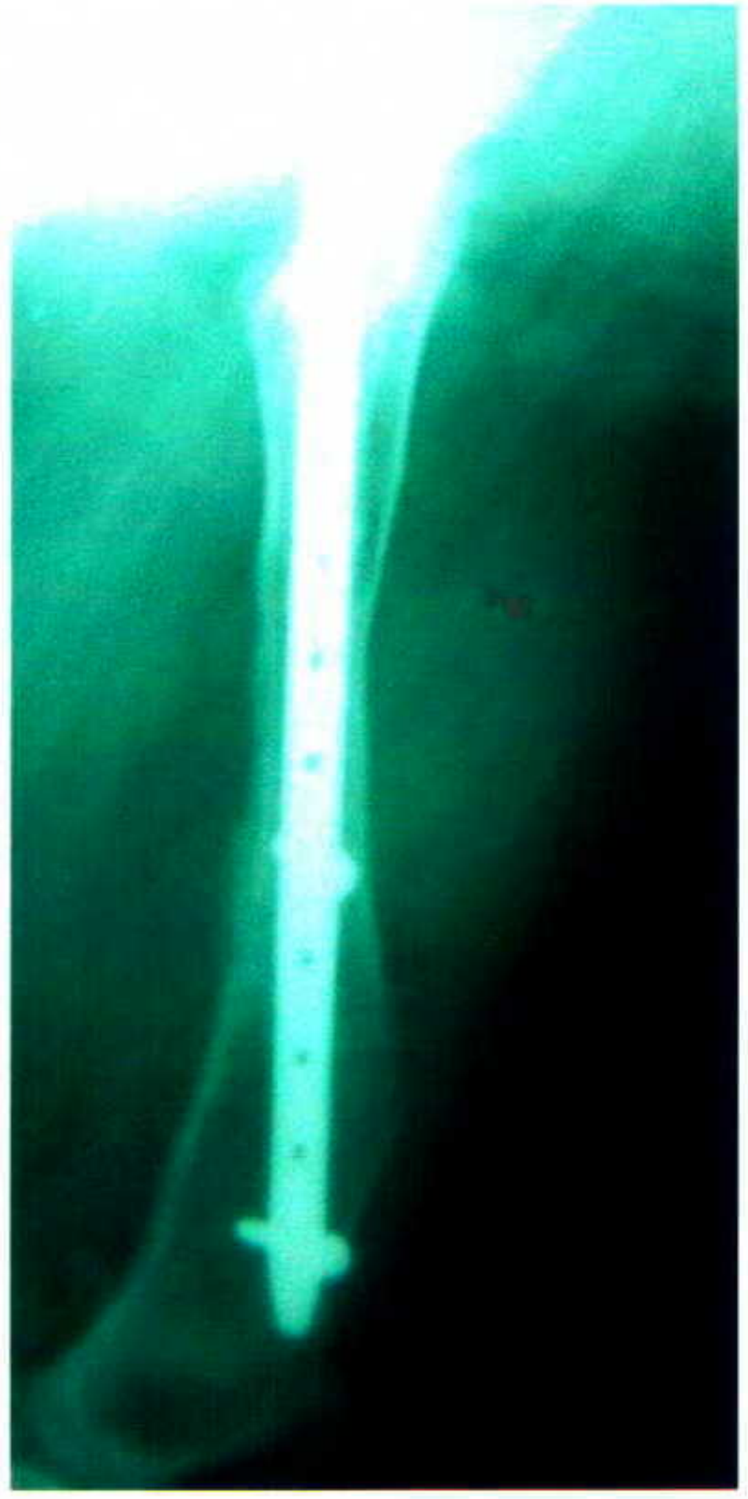


Fig. 40

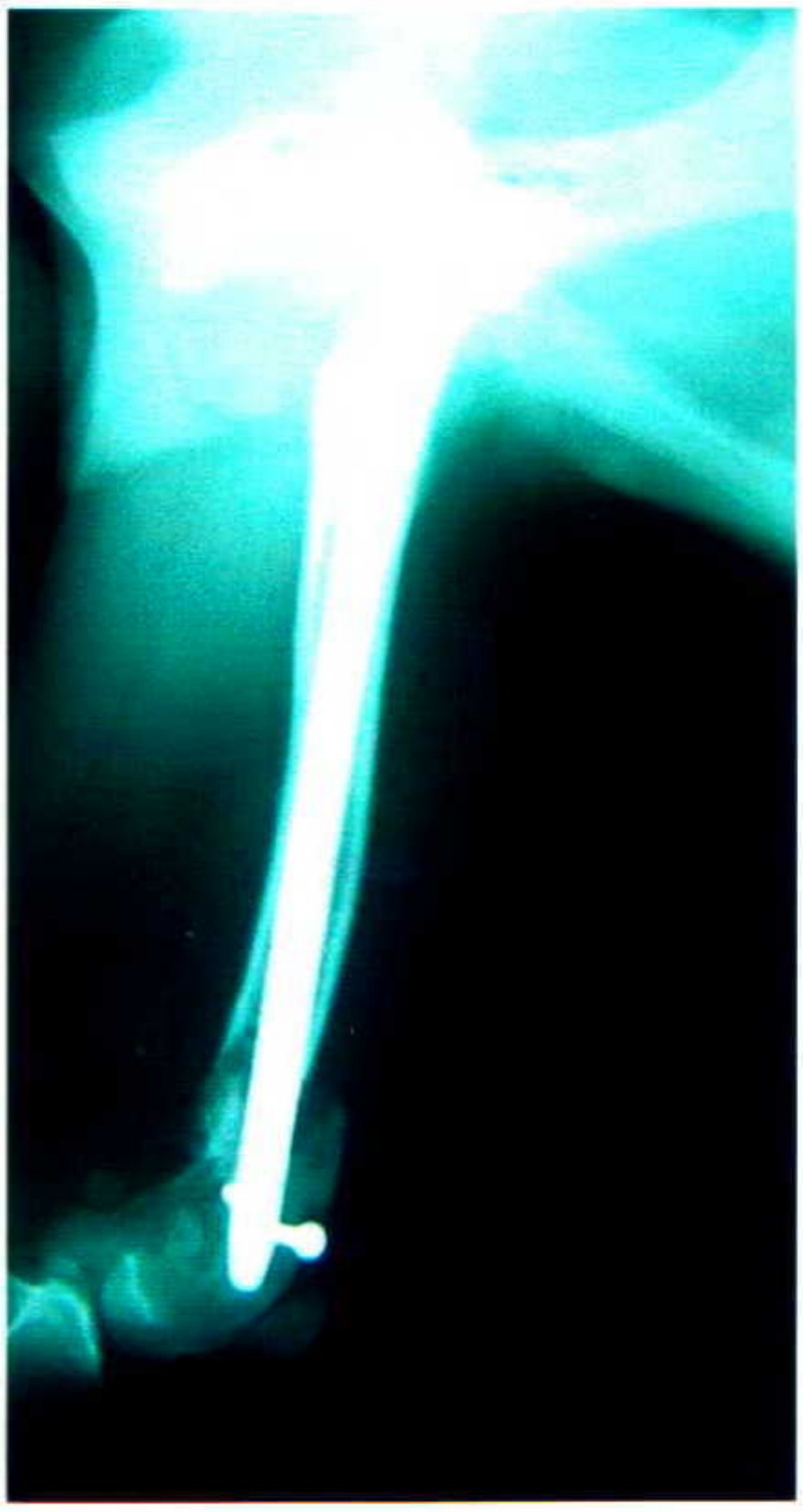


Fig. 41

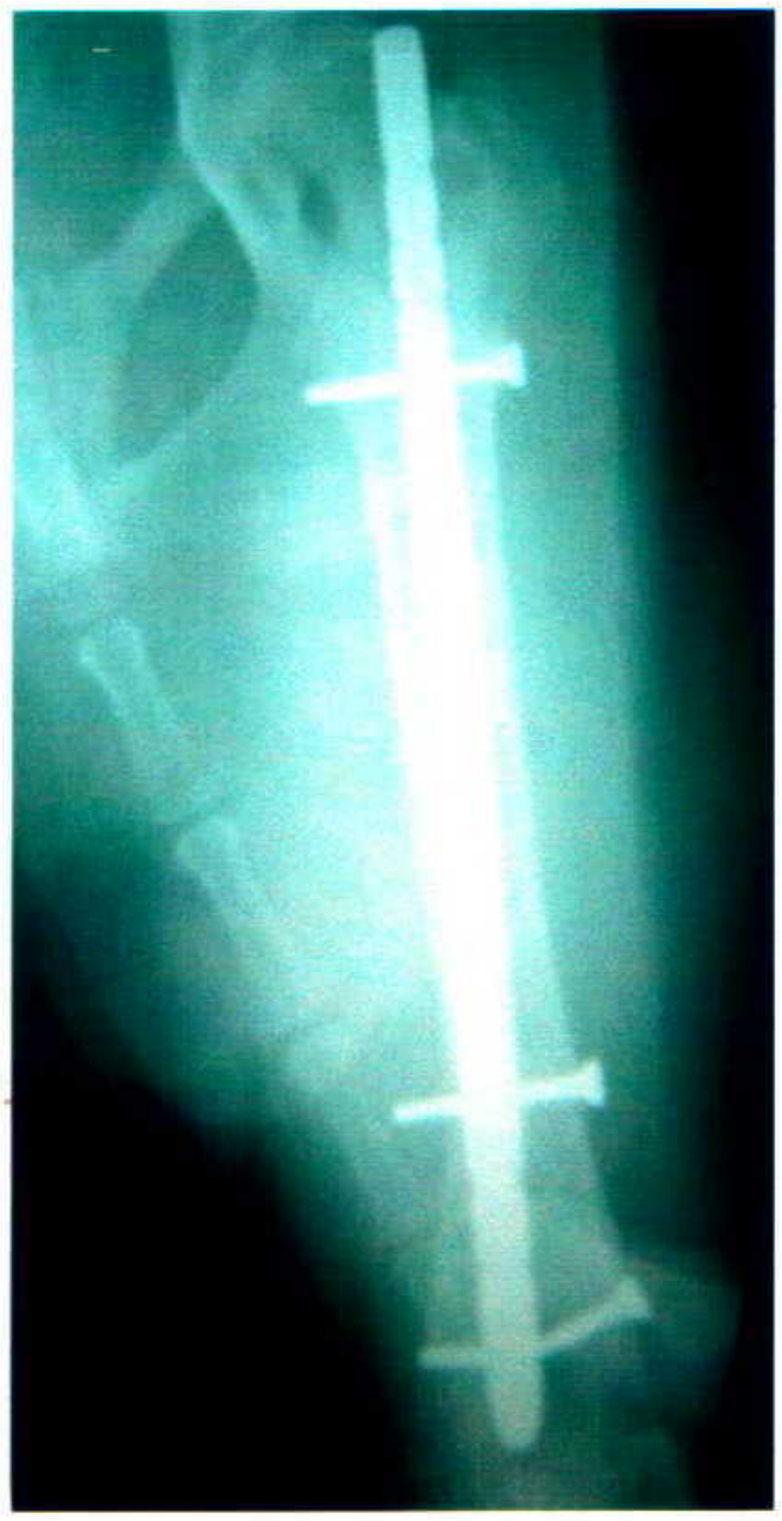


Fig. 42

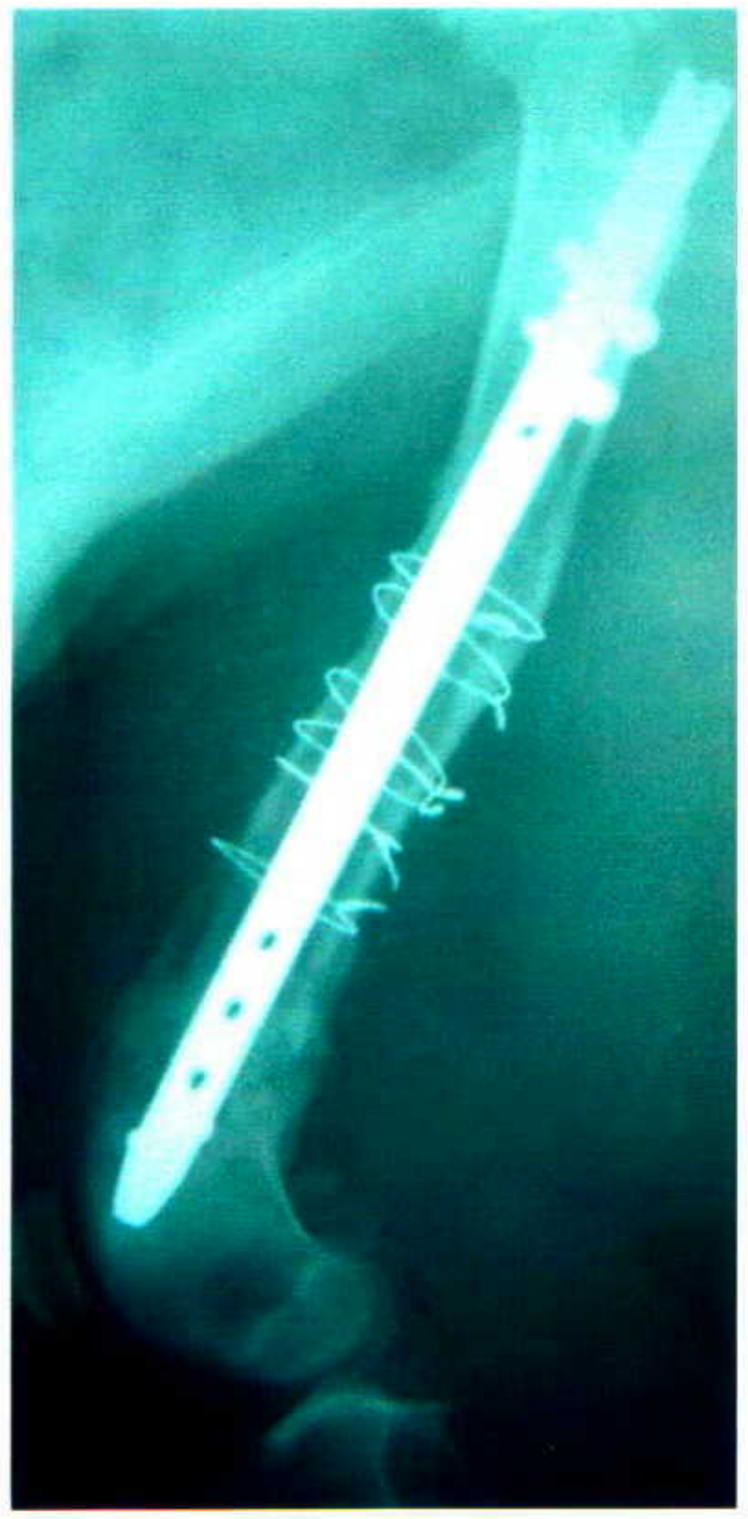


Fig. 43

bridging callus at 30 days old radiograph and cortical continuity at 90 days radiographs (Fig 40). In dog 4, the sign of delayed union was present at 90 days post operative radiograph (Fig 41) in which fracture line was still evident at the cranial aspect of the fracture site. The dynamization has been recommended in such cases if signs of delayed union were present at 12 weeks post operatively. (Bucholz *et al* 1987). In dog 6, cortical and medullary continuity was evident at this stage (Fig 42). In dog 7, the signs of bridging callus were evident at 40 days post operative radiograph (Fig 43).

Group II:

In dog 1, hypertrophic bridging callus (Fig 44) was seen at one month old radiograph. This was due to the dislodgement of the proximal transcortical screw. This would have resulted in increased micro motion at the fracture site that eventually leads to excessive callus formation. In dog 3, excessive periosteal bridging callus was evident at 90 days post operative radiograph (Fig 45). In dog 5, with humerus mid shaft fracture, showed excellent healing with cortical and medullary continuity at 40 post operative days (Fig 46). In dog 7, excessive periosteal bridging callus (Fig 47) was evident at 30 days post operatively. Similar findings were evident in dogs 8, 9, 10 (Fig 48, 49, 50) and 12 (Fig 51) of this group. Rand *et al* (1981) opined that intramedullary fixation leads to excessive periosteal callus formation. Moses *et al* (2002) also reported the mean time of radiographic union as 8.8 (+/- 2.3) weeks.

Fig 44: 30th day post operative radiograph (lateral view) showing formation of excessive bridging callus due to dislodgement of the proximal screw (G-II, D-1).

Fig 45: 90th day post operative radiograph (lateral view) showing formation of excessive bridging callus at caudal aspect of bone, cortical continuity evident at cranial aspect (G-II, D-3).

Fig 46: 40th day post operative radiograph (lateral view) showing complete cortical continuity at the fracture site, fracture line not visible (G-II, D-5).

Fig 47: 30th day post operative radiograph (craniocaudal view) showing formation of excessive bridging callus (G-II, D-7).

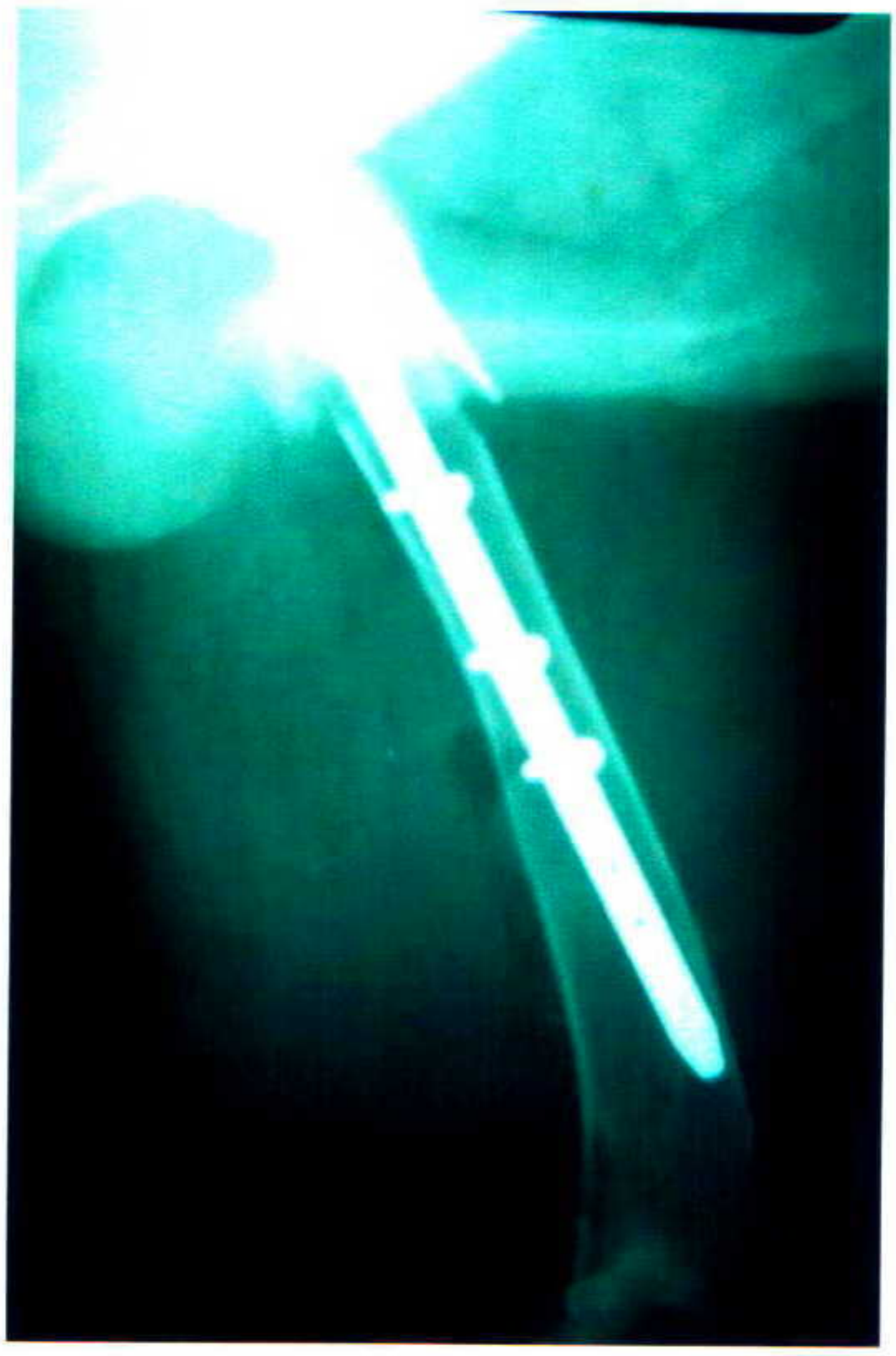


Fig. 44

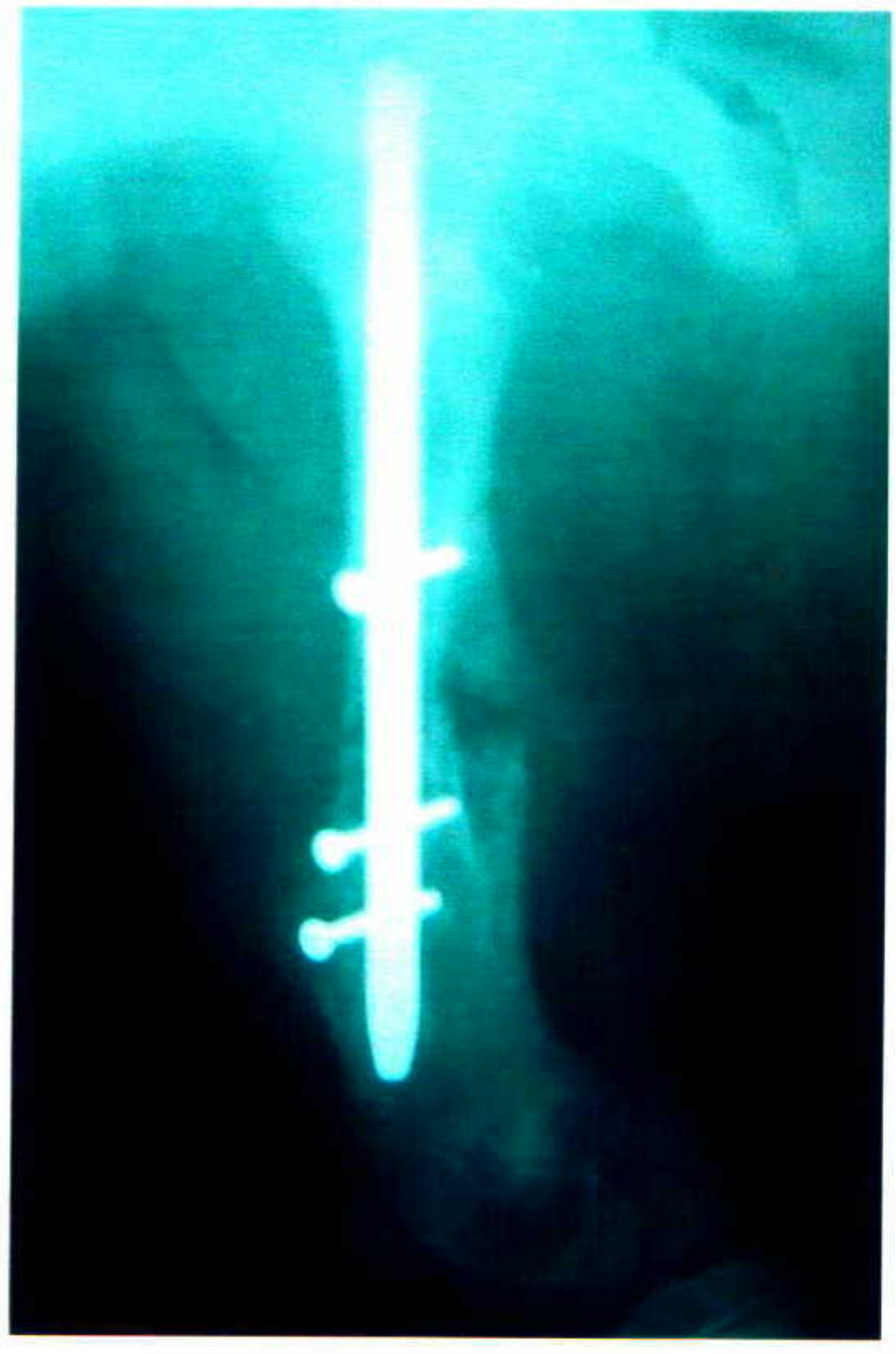


Fig. 45

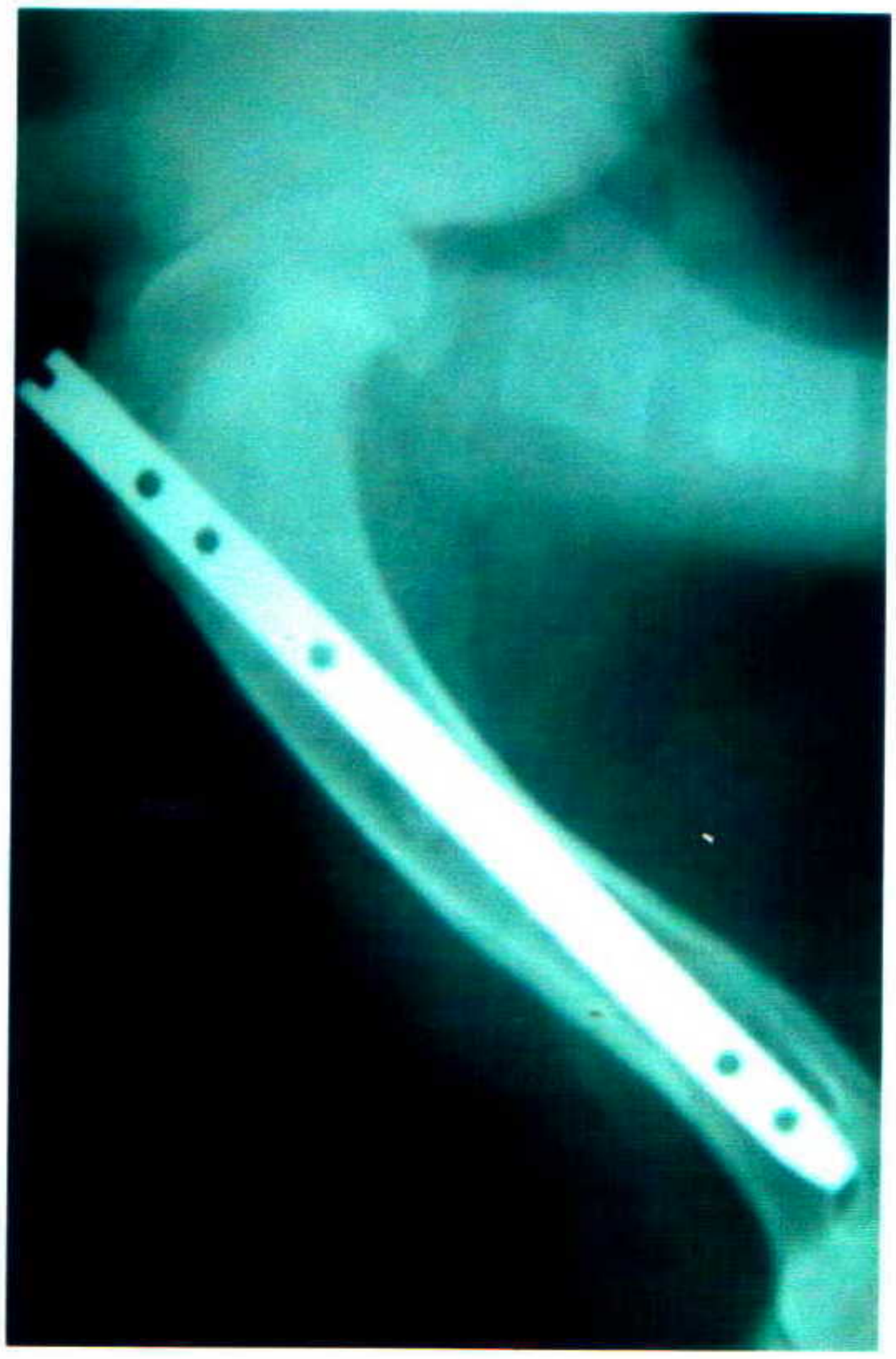


Fig. 46

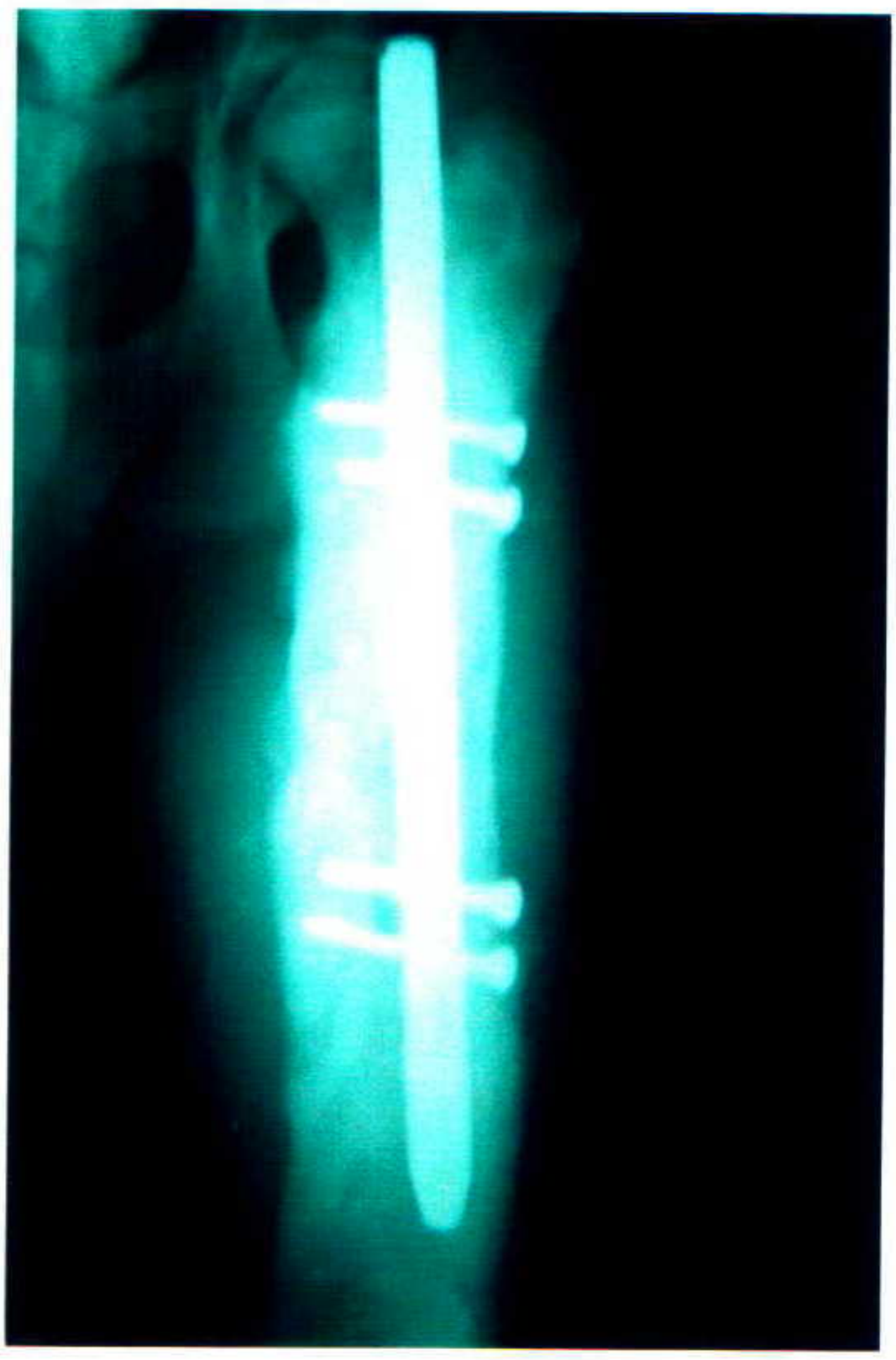


Fig. 47

Fig 48: 30th day post operative radiograph (lateral view) showing formation of excessive periosteal bridging callus at caudal aspect of fracture site (G-II, D-8).

Fig 49: 40th day post operative radiograph (lateral view) showing formation of excessive bridging callus at caudal aspect of bone with evidence of cortical continuity (G-II, D-9).

Fig 50: 60th day post operative radiograph (lateral view) showing formation of complete cortical continuity, fracture line not visible (G-II, D-10).

Fig 51: 90th day post operative radiograph (craniocaudal view) showing formation of excessive bridging callus right limb and evidence of cortical continuity in the left limb, the fracture line is evident in right limb at this stage (G-II, D-12).

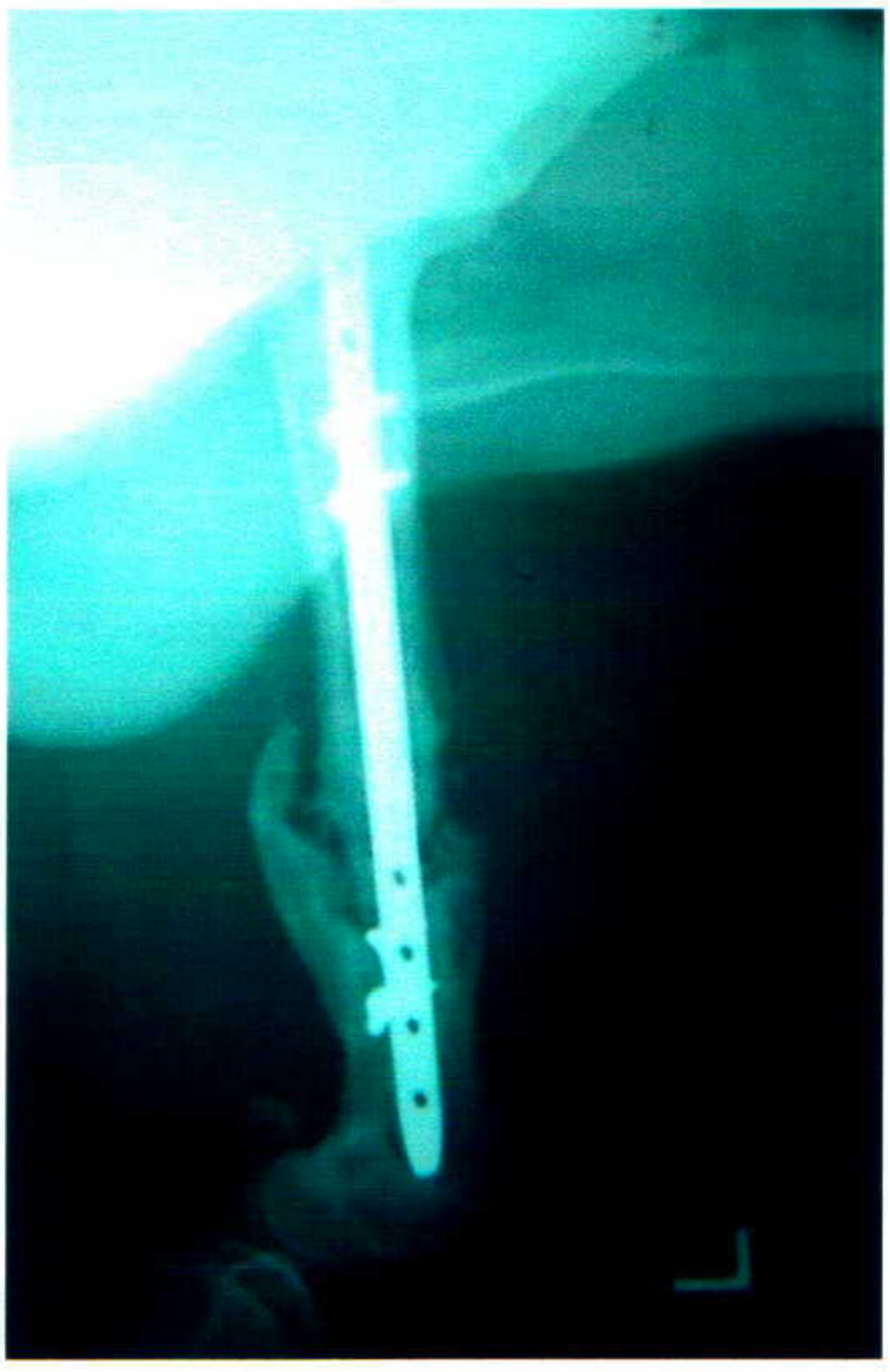


Fig. 48

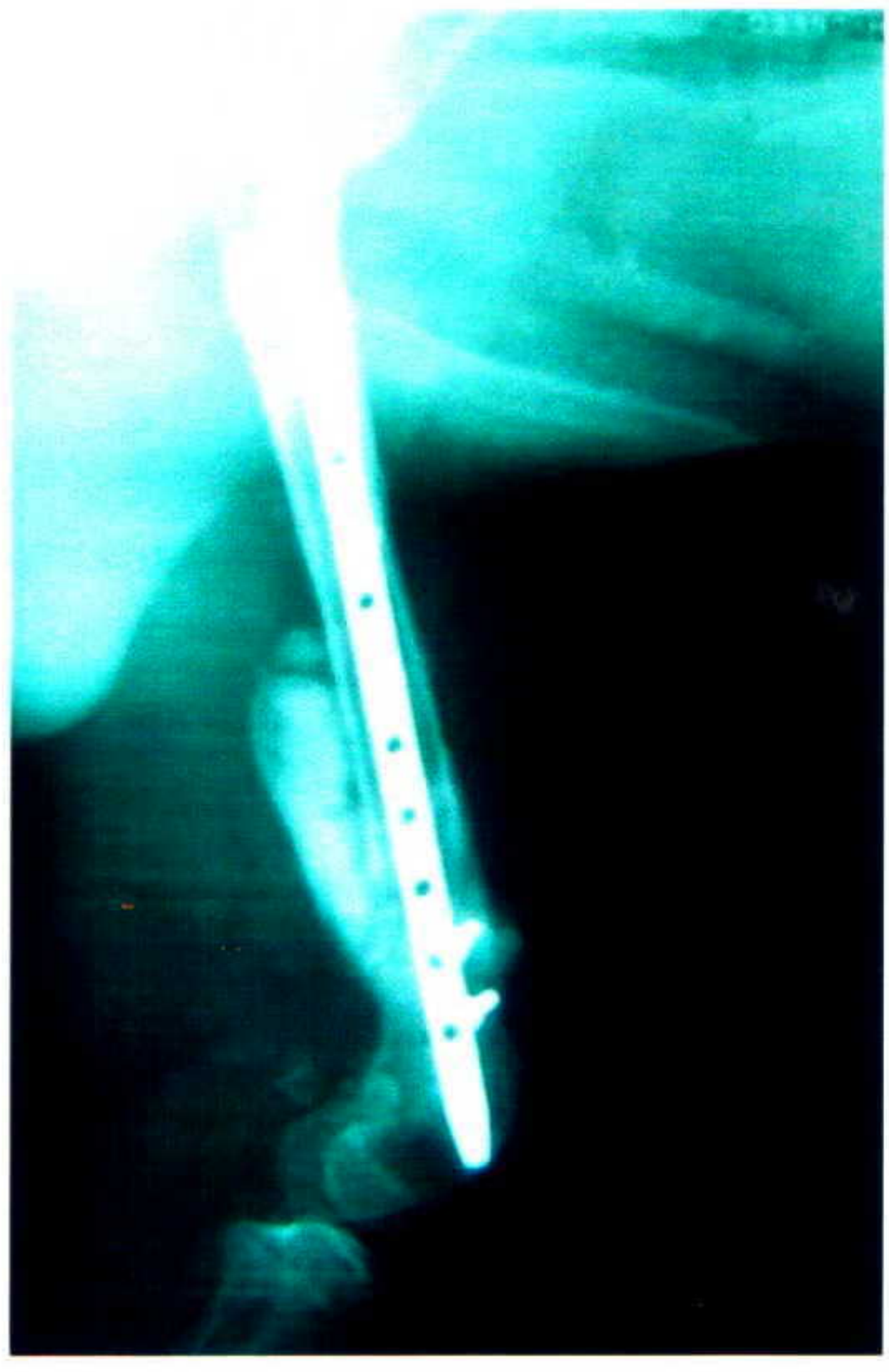


Fig. 49

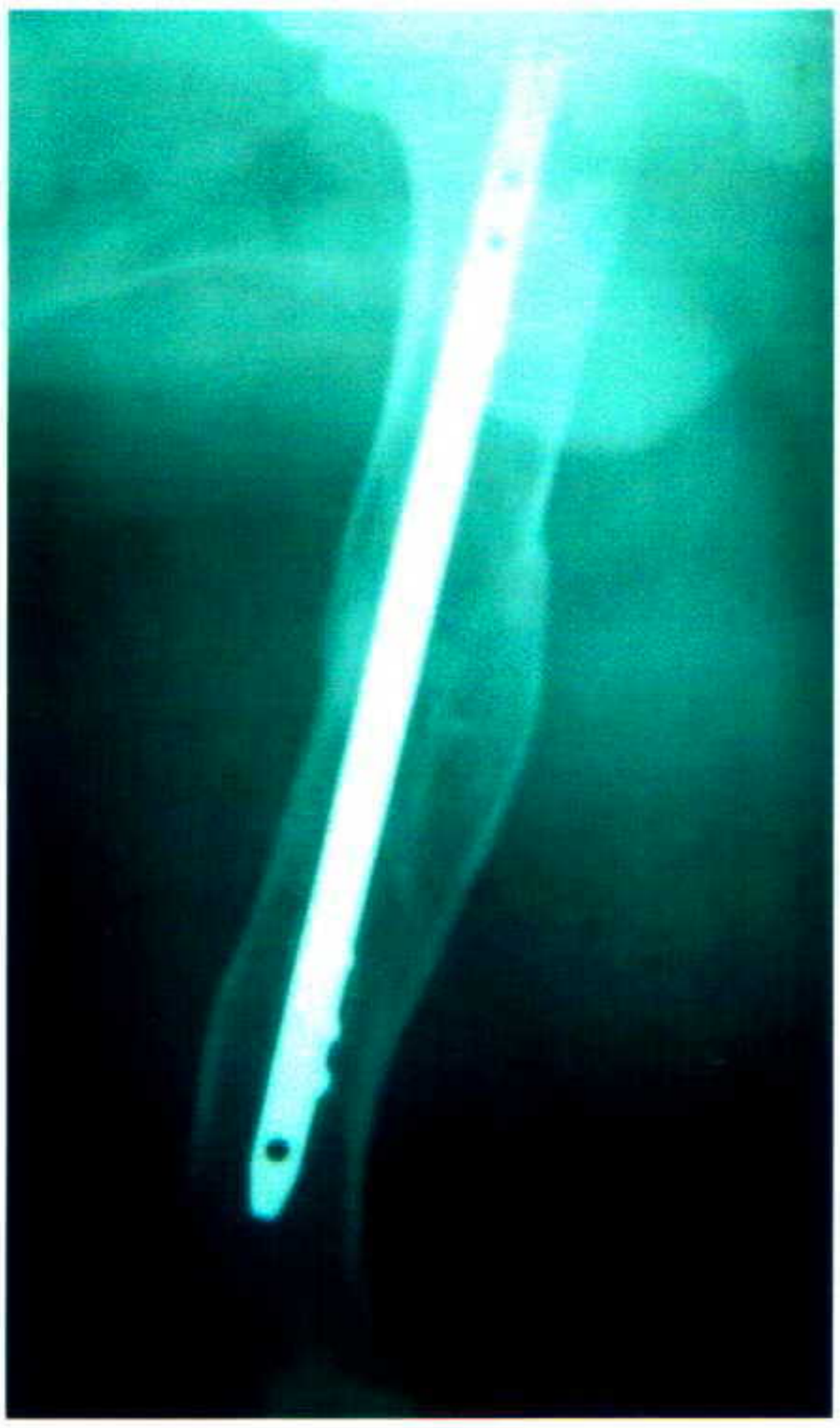


Fig. 50

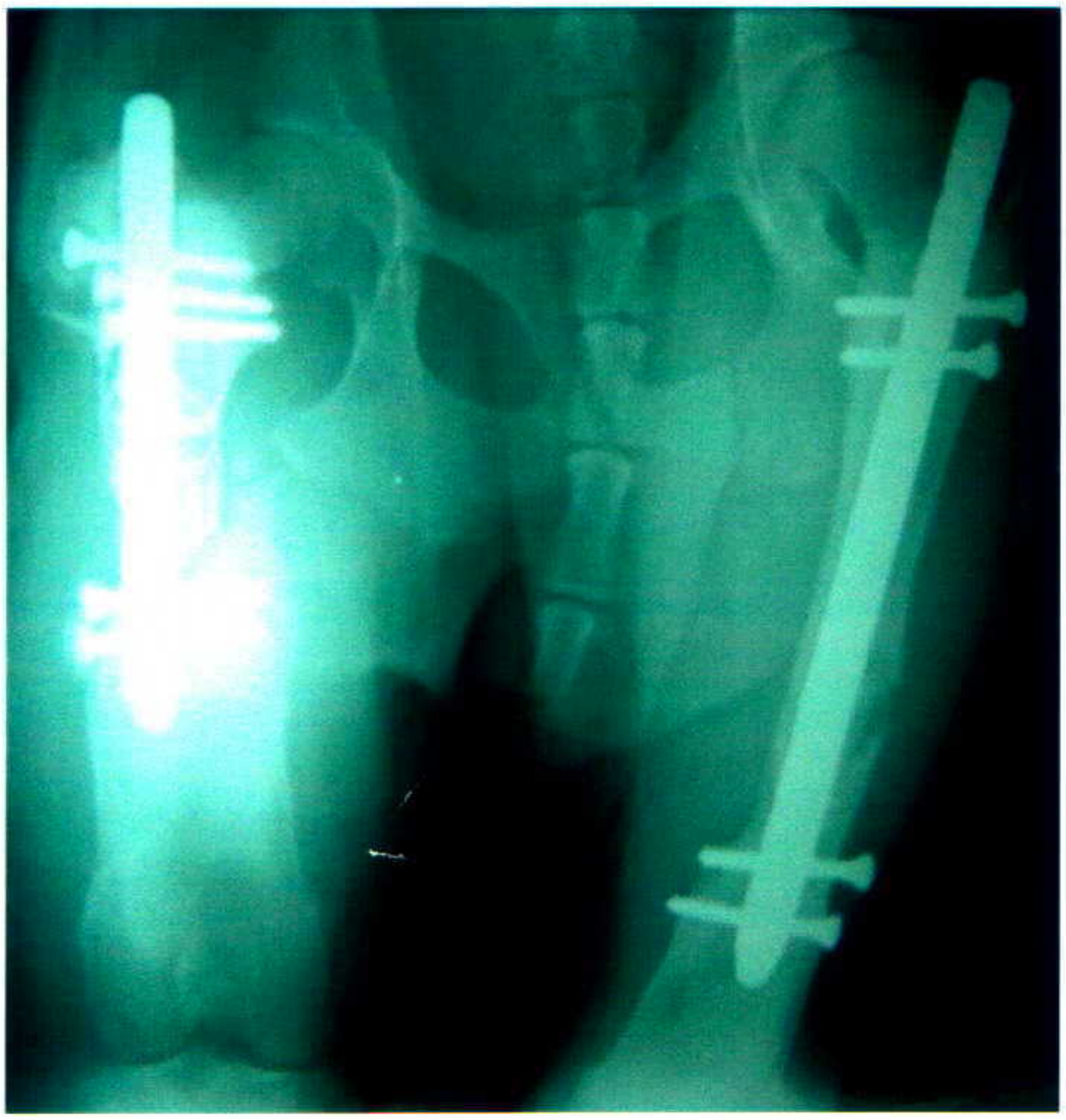


Fig. 51

The results suggested that signs of radiographic union were present in both the groups from 30-90 days post operatively.

4.5.3: Above 90 post operative days

Group I

In group I in almost all cases the fracture line was not visible. Callus was organized with cortical continuity established (Fig 52, 53, 55) . In dog 5, signs of osteomylitis were present at 180 days post operatively which also revealed loss of bone from the caudal aspect of the fracture site (Fig 54). The cranial aspect revealed the cortical continuity. However the implant was still bearing the weight of the affected limb quite satisfactorily. In all the dogs except dog 5, the callus formation along with the cortical continuity had established.

Group II

All the dogs except dog 11 had excellent radiographic union at this stage. In dog 1, hypertrophic bridging callus was evident at 180 days (Fig 56). Dog 3 showed complete cortical continuity at 180 days (Fig 57). Similarly dog 7 had satisfactory radiographic union at 135 days post operative radiograph (Fig 58). Dog 12 showed satisfactory radiographic union at 120 days post operative radiograph in left femur however at the same stage osteomyelitis was evident in right femur (Fig 59).

Fig 52: 180th day post operative radiograph (lateral view) showing formation of cortical continuity in a tibial fracture with stable implant (G-I, D-1).

Fig 53: 180th day post operative radiograph (craniocaudal view) showing complete healing with complete cortical continuity and incorporation of irreducible chips into the fracture callus (G-I, D-2).

Fig 54: 180th day post operative radiograph (lateral view) showing evidence of osteomylitis and osteolytic changes leading to extensive bone loss in the caudal aspect of the fracture bone. (G-I, D-5).

Fig 55: 120th day post operative radiograph (lateral view) showing complete healing with complete cortical continuity (G-I, D-7).

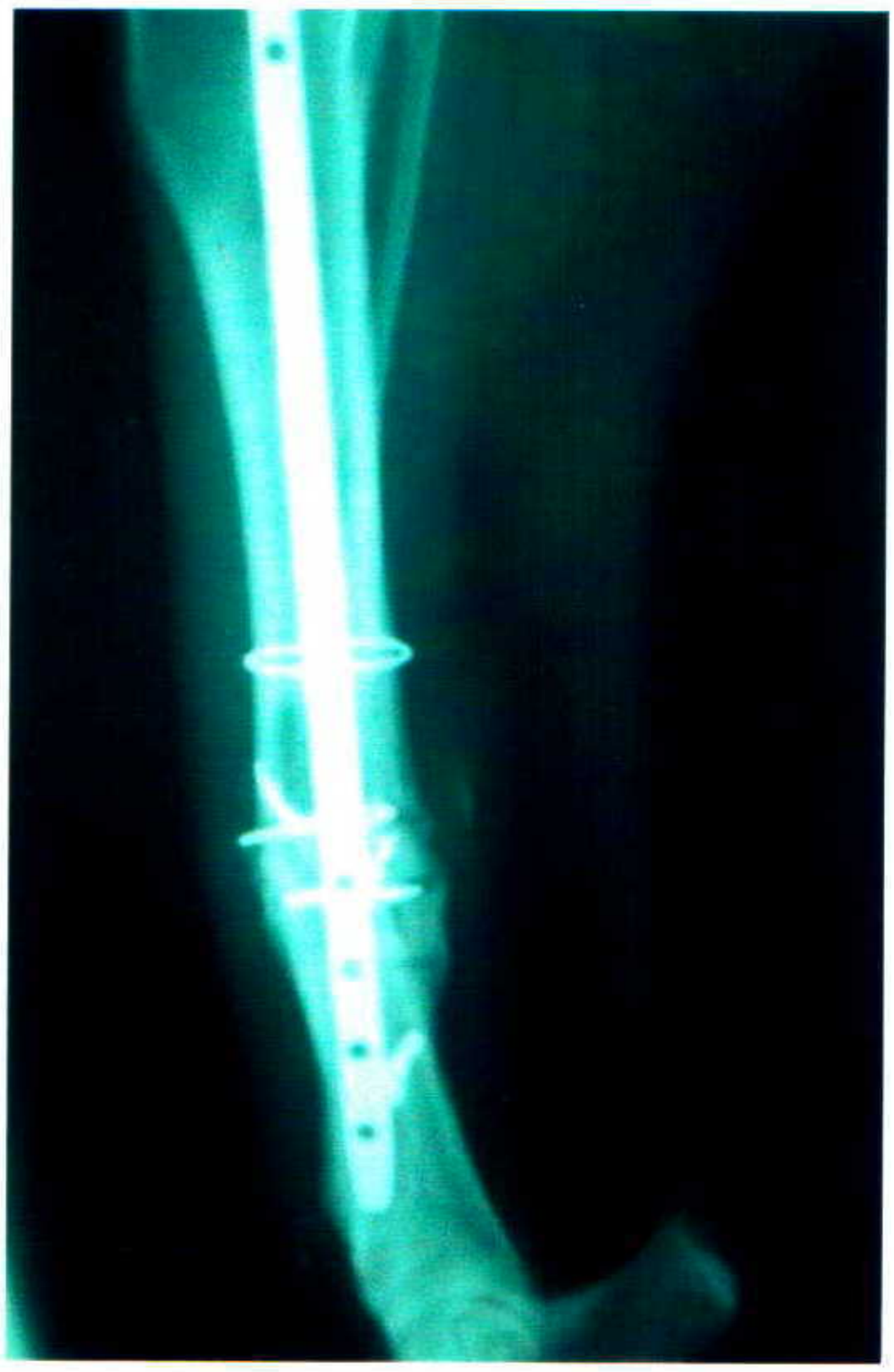


Fig. 52

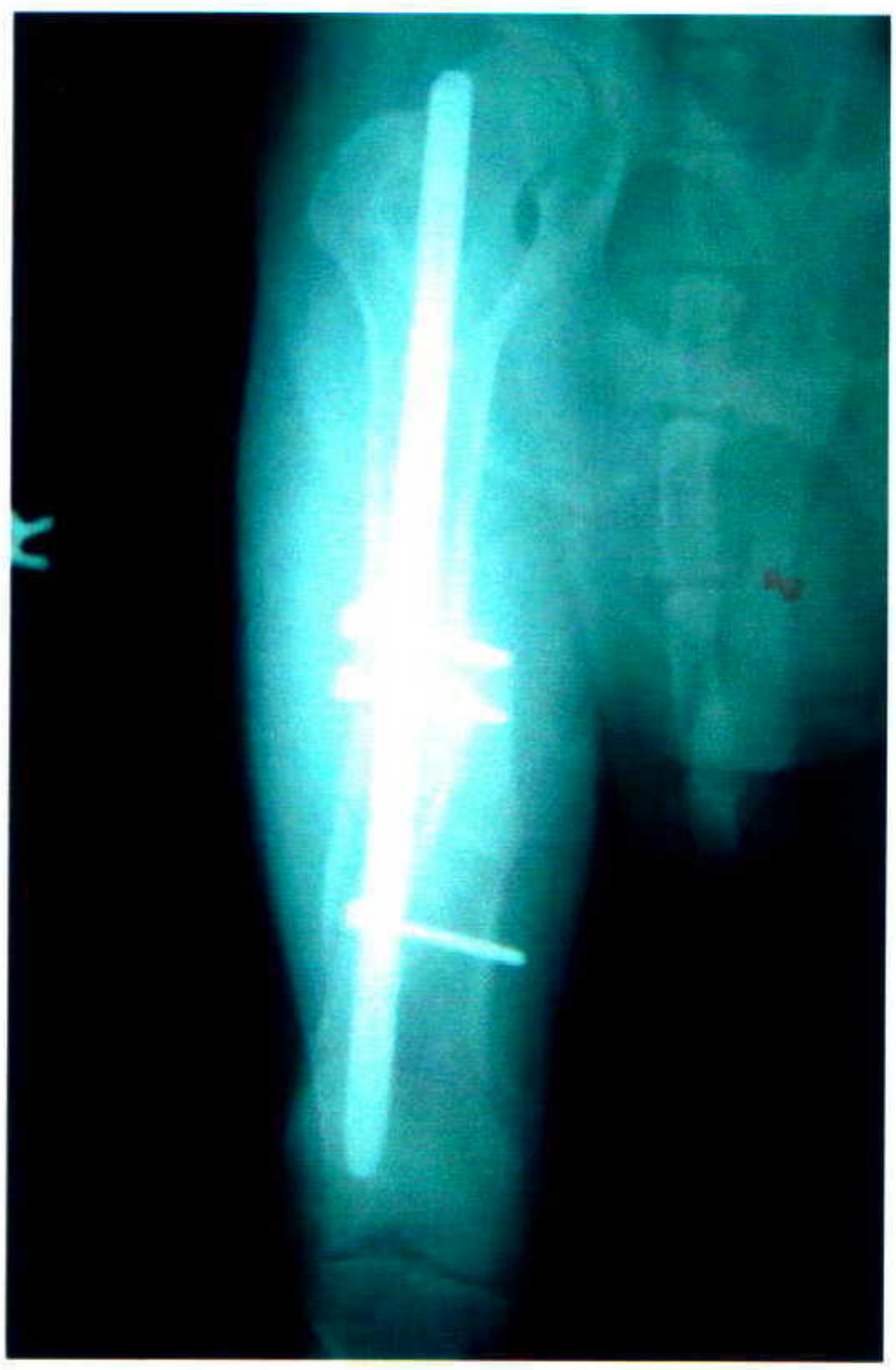


Fig. 53

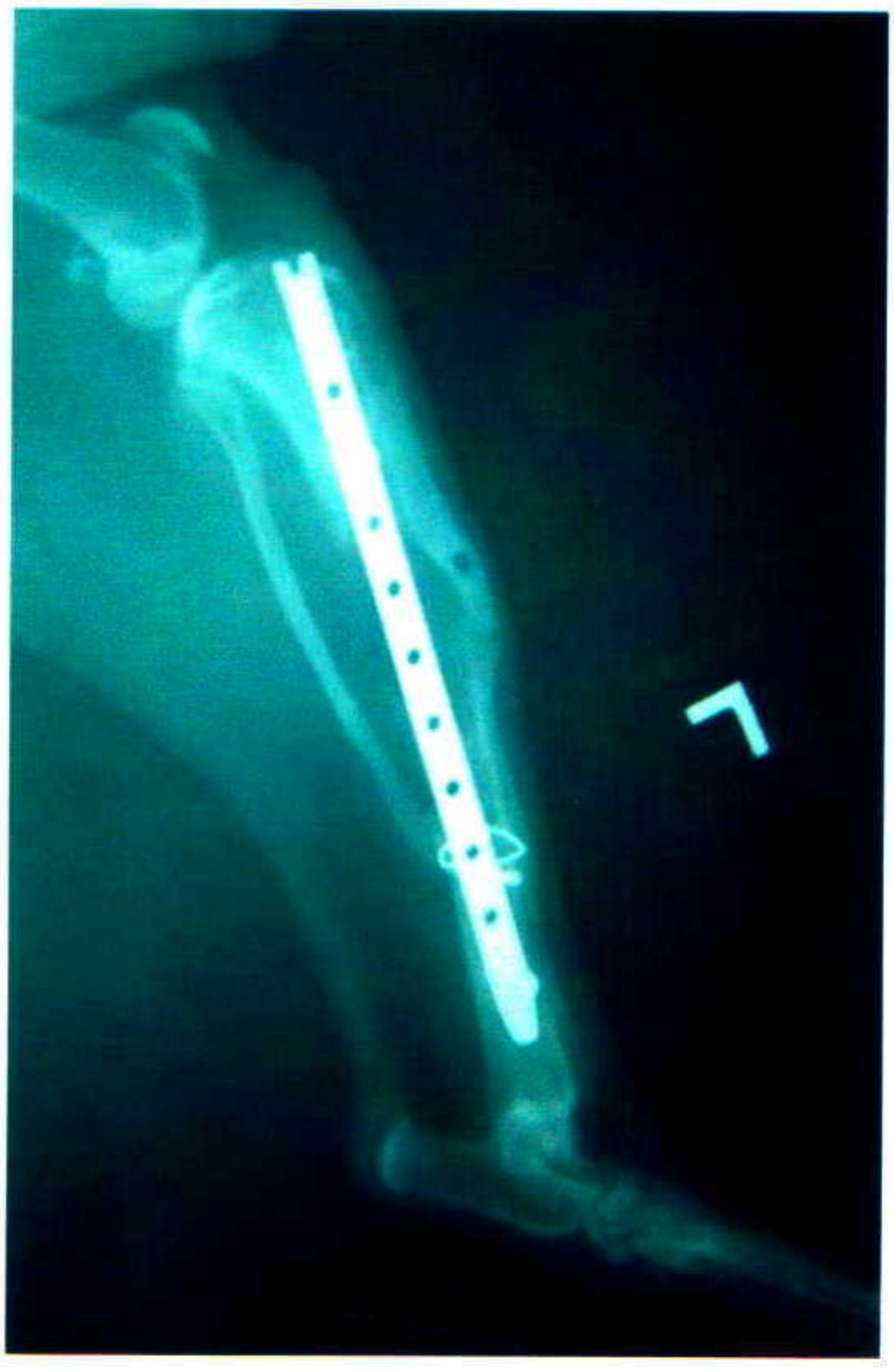


Fig. 54

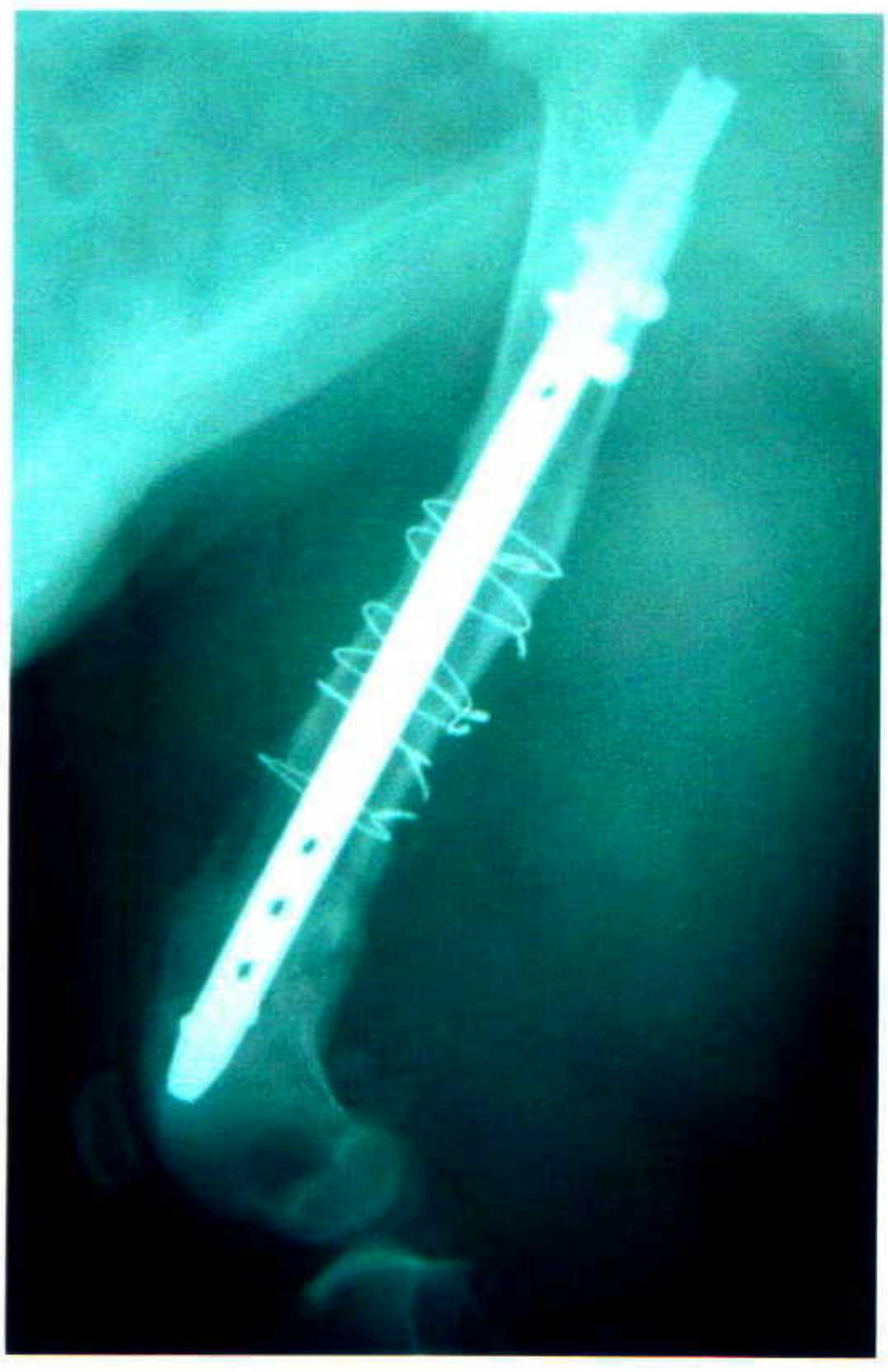


Fig. 55

Fig 56: 180th day post operative radiograph (lateral view) showing formation of hypertrophic bridging callus at the fracture site due to breakage of distal screw and dislodgement of proximal screw near the fracture site leading to excessive micro motions (G-II, D-1).

Fig 57: 180th day post operative radiograph (craniocaudal view) showing complete healing with complete cortical continuity, the IL nail is embedded into the bone due to growth of dog in convalescent period (G-II, D-3).

Fig 58: 140th day post operative radiograph (lateral view) showing complete healing of fracture with establishment of cortical continuity (G-II, D-7).

Fig 59: 120th day post operative radiograph (craniocaudal view) showing complete healing with complete cortical continuity in left limb and evidence of osteomyelitis in right limb (G-II, D-12).

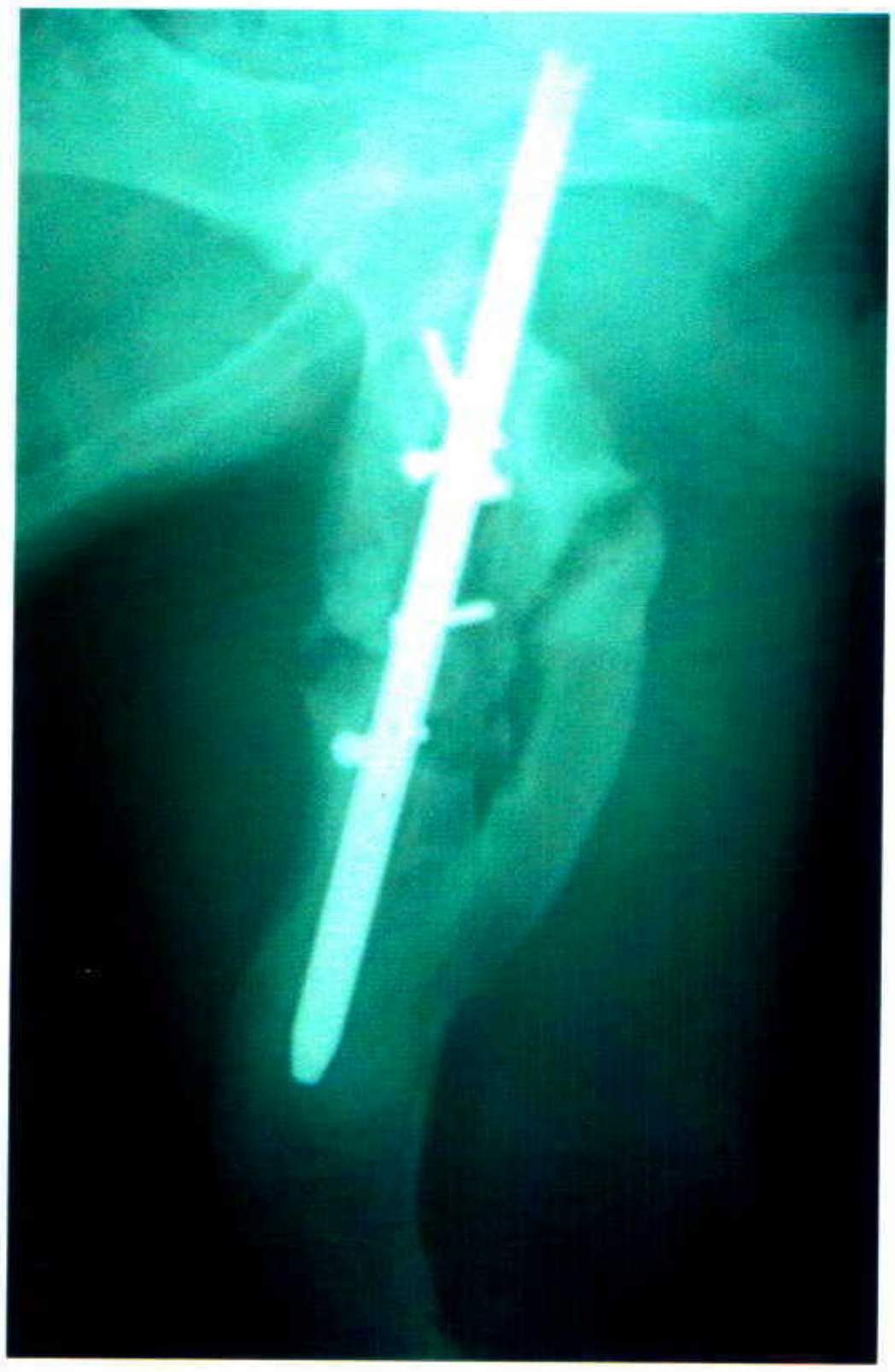


Fig. 56

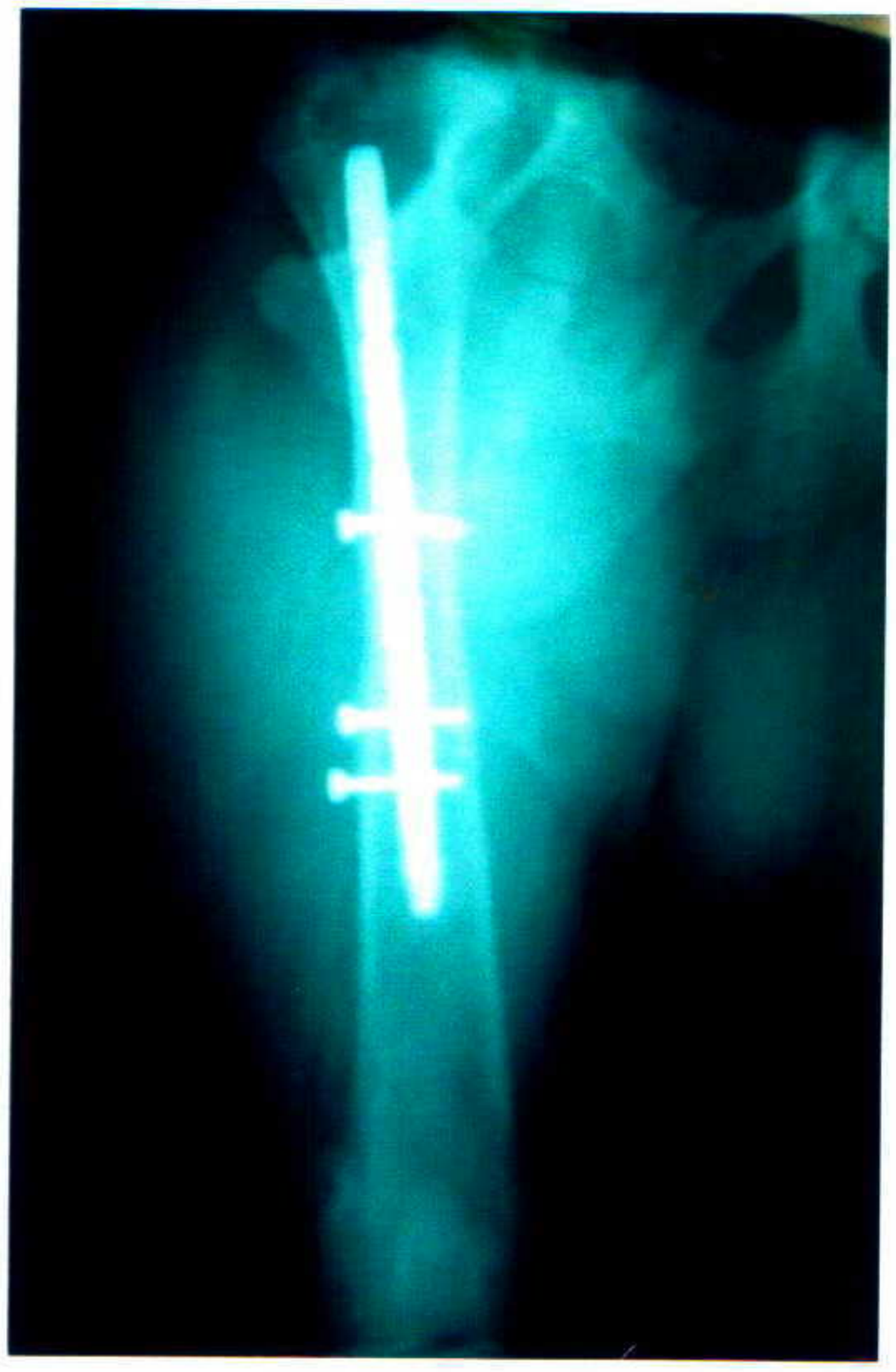


Fig. 57

Fig. 58

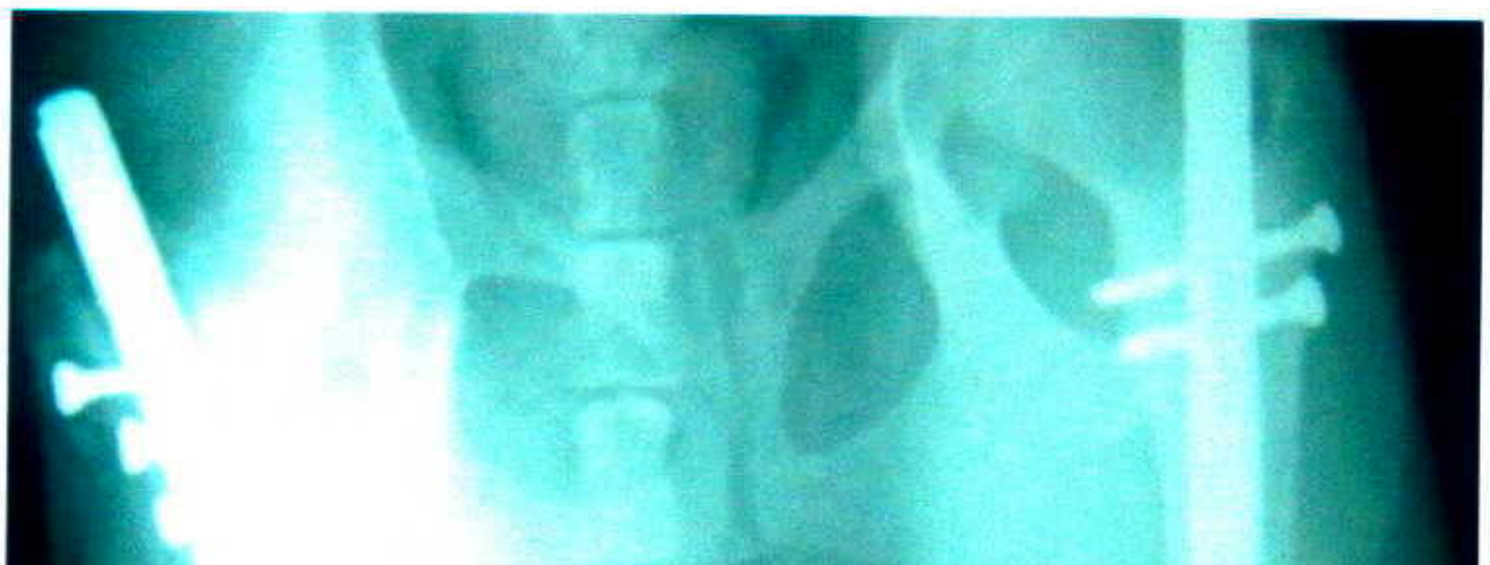


Fig. 59

4.6 Clinical Outcome

Limb usage during the convalescent period was categorized using the classification devised by Fox *et al* (1995) as excellent, good, fair and poor.

4.6.1 Group I

In group I in all the cases except dog 5, final limb usage was found to be excellent. In dog 5, which developed osteomyelitis the final out come, was fair. The mean follow up time for dogs in this group was 10.14 months after surgery ranging from 2 months to 16 months after surgery.

4.6.2 Group II

In group II, final out come was excellent in dogs 1, 3, 4, 5, 6, 7, 8, 9, 10. In dog 2, the follow up was lost due to non compliance of the owner. In dog 11, final out come was rated poor due to failure of reduction at 1 month after surgery. The mean follow up time for dogs in this group was 6.77 months after surgery ranging from 2 months to 16 months after surgery.

For 18 dogs for which long term follow up was available, either direct physical examination or contact with owners on phone, 15 dogs had excellent clinical out come. Similar high rate of excellent clinical out come using this fixation modality has been reported by various other workers like Dueland *et al* (1999), Larin *et al* (2001) and Raghunath (2002). Clinical outcome was comparable for both the groups suggesting that once the fracture gets healed the

long term clinical outcome or final limb usage is independent of number of transcortical screws in distal fragment of the fractured bone.

4.7 Complications

Post operative complications associated with implant were noted.

4.7.1 Group I

In group I, in dogs 2 and 3 misdirected screws were noticed in immediate post operative radiographs (Fig 60, 61). Durall *et al* (1994) also reported that failure to match the transcortical screws in nail holes as a common complication associated with IL nail. However, this did not interfere with the fracture healing and final clinical outcome. Raghunath (2002) also experienced misdirected screw during his study using static intramedullary IL nailing. Medoff (1986) opined that fractures that were below mid shaft had tendency for misdirected screws in the distal fragments. This was likely due to the toggling of the nail in the medullary canal which leads to missing of nail hole while drilling. He suggested that sharp drill bit may be used and excessive pressure on lateral aspect of the bone cortex be avoided during drilling to avoid toggling of the nail in the medullary canal. In dogs 4, 6 and 7 distal screw bending was evident on radiographs (Fig 62, 63, 64). Bucholz et al (1987) opined that the distal femoral fracture, combined with early loading by weight bearing, results in fatigue failure of the device. Hajek *et al* (1993) also opined that use of single distal transcortical screw was enough to counteract torsional or axial load however for distal femur fractures it may not

Fig 60: Immediate post operative radiograph (lateral view) showing misdirected screw in the distal fragment (arrow) (G-I, D-1).

Fig 61: Immediate post operative radiograph (lateral view) showing misdirected screw in the distal fragment (arrow) (G-I, D-2).

Fig 62: 10th day post operative radiograph (craniocaudal view) showing bending of the distal transcortical screw in a distal femur fracture (arrow) (G-I, D-4).

Fig 63: 60th day post operative radiograph (craniocaudal view) showing bending of the distal transcortical screw in a distal femur fracture (arrow), cortical continuity established (G-I, D-6).

Fig 64: 20th day post operative radiograph (craniocaudal view) showing bending of the distal transcortical screw in a segmental femur fracture (arrow), signs of periosteal reaction is evident at this stage (G-I, D-7).

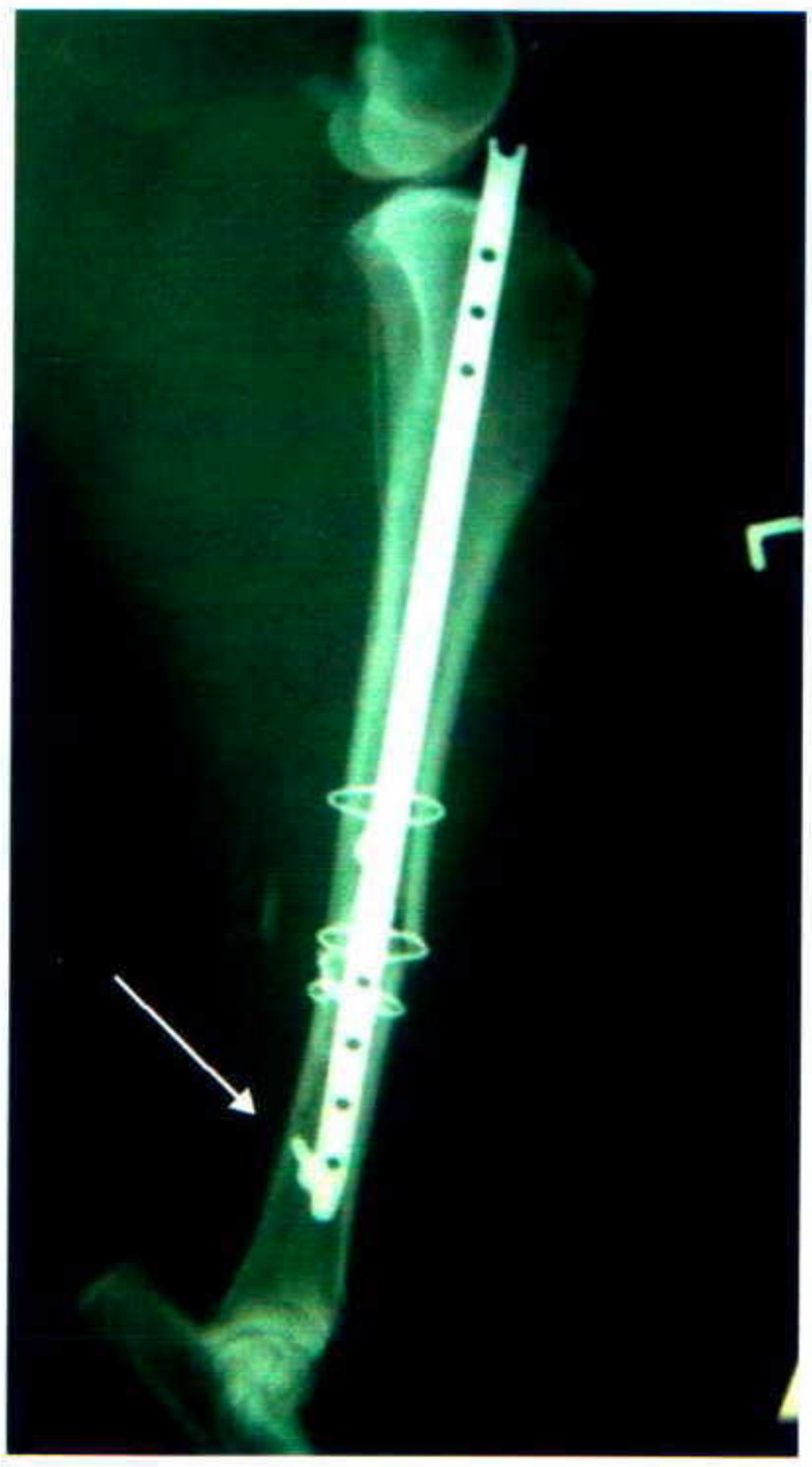


Fig. 60

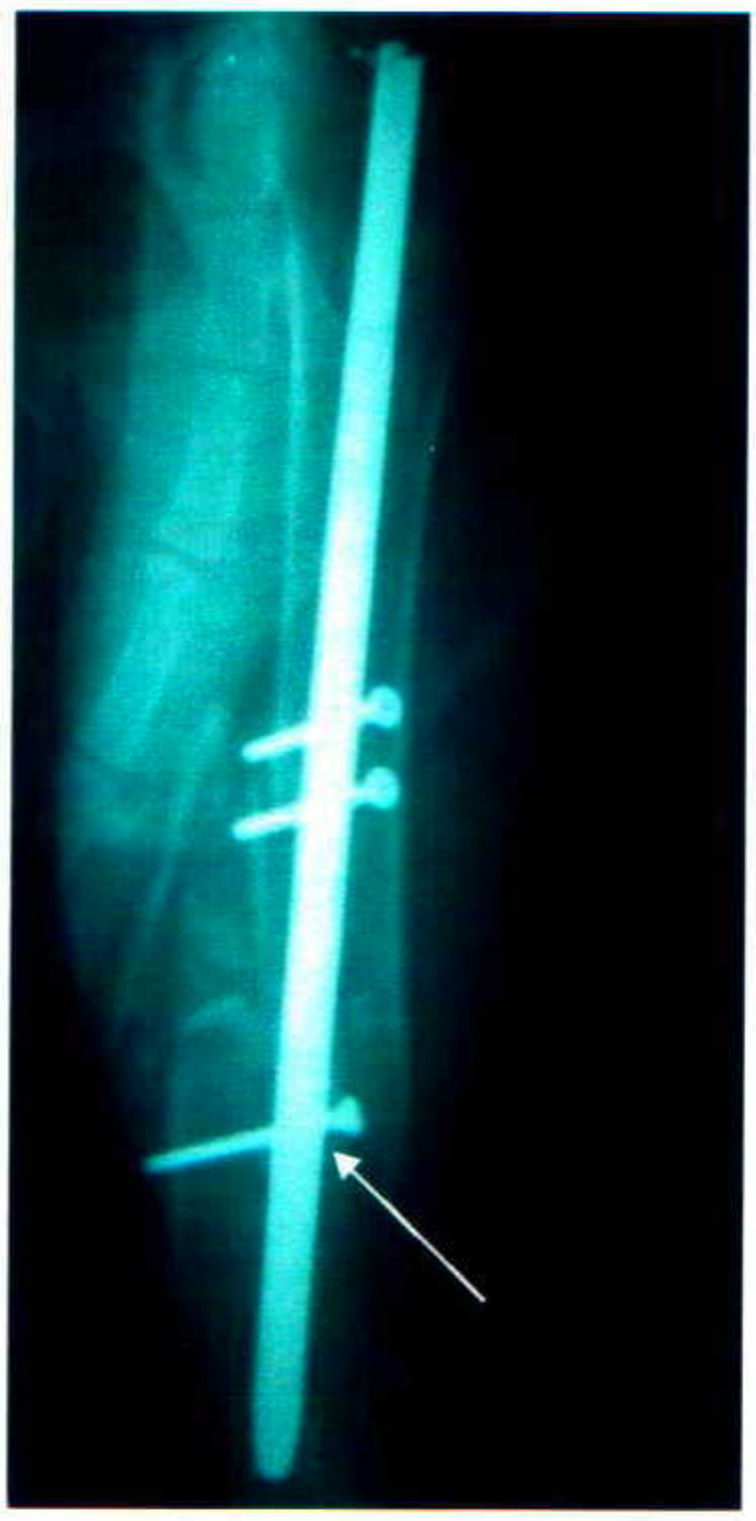


Fig. 61

Fig. 62

Fig. 63

Fig. 64

provide the adequate stabilization in saggital plain, thus might lead to delayed union or non union. Similarly in this group as well, dog 4 with distal femur fracture treated with single distal transcortical screw developed delayed union when the bent screw broke 1 mo post operatively.

The results of present study suggested that use of only one distal transcortical screw for fractures distal to isthmus will influence the rate of fatigue failure for screws *in vivo*. Zuckerman *et al* (1981) also reported that use of a single distal transcortical screw was cause of one non union in his series of fractures treatments in human patients.

4.7.2 Group II

In group II, dog 1, proximal screw was dislodged and proximal distal screw was broken at about 1 month post operative convalescent period (Fig 65). Durall and Diaz (1996) also reported that screw loosening as one of the complication in static intramedullary IL nailing. The dislodgement of the proximal screw must have led to the increased movements of the fracture fragments along the healing callus and the proximal distal screw got broken due to increased continuous abrasive frictional movements at the holes entry points in the nail. In dog 3, distal screw got backed out from the far cortex at around 3 months post operative convalescent period (Fig 66). This could be attributed to the fact that rapid progression to full weight bearing and lack of fixed or rigid fixation must have led to the loosening of the screws. In dog 8, immediate post operative

Fig 65: 180th day post operative radiograph (lateral view) showing dislodgement of the proximal screw and breakage of distal screw close to the fracture line, signs of hypertrophic callus also evident (G-II, D-1).

Fig 66: 90th day post operative radiograph (craniocaudal view) showing back out of the distal screw from far cortex of bone (arrow), cortical continuity is evident (G-II, D-2).

Fig 67: Immediate post operative radiograph (lateral view) showing misdirected screw in the distal fragment (arrow) (G-II, D-8).

Fig 68: 30th day post operative radiograph (craniocaudal view) showing breakage of the proximal of the two distal transcortical screws in the distal fragment in distal femur fracture (arrow) (G-II, D-9).

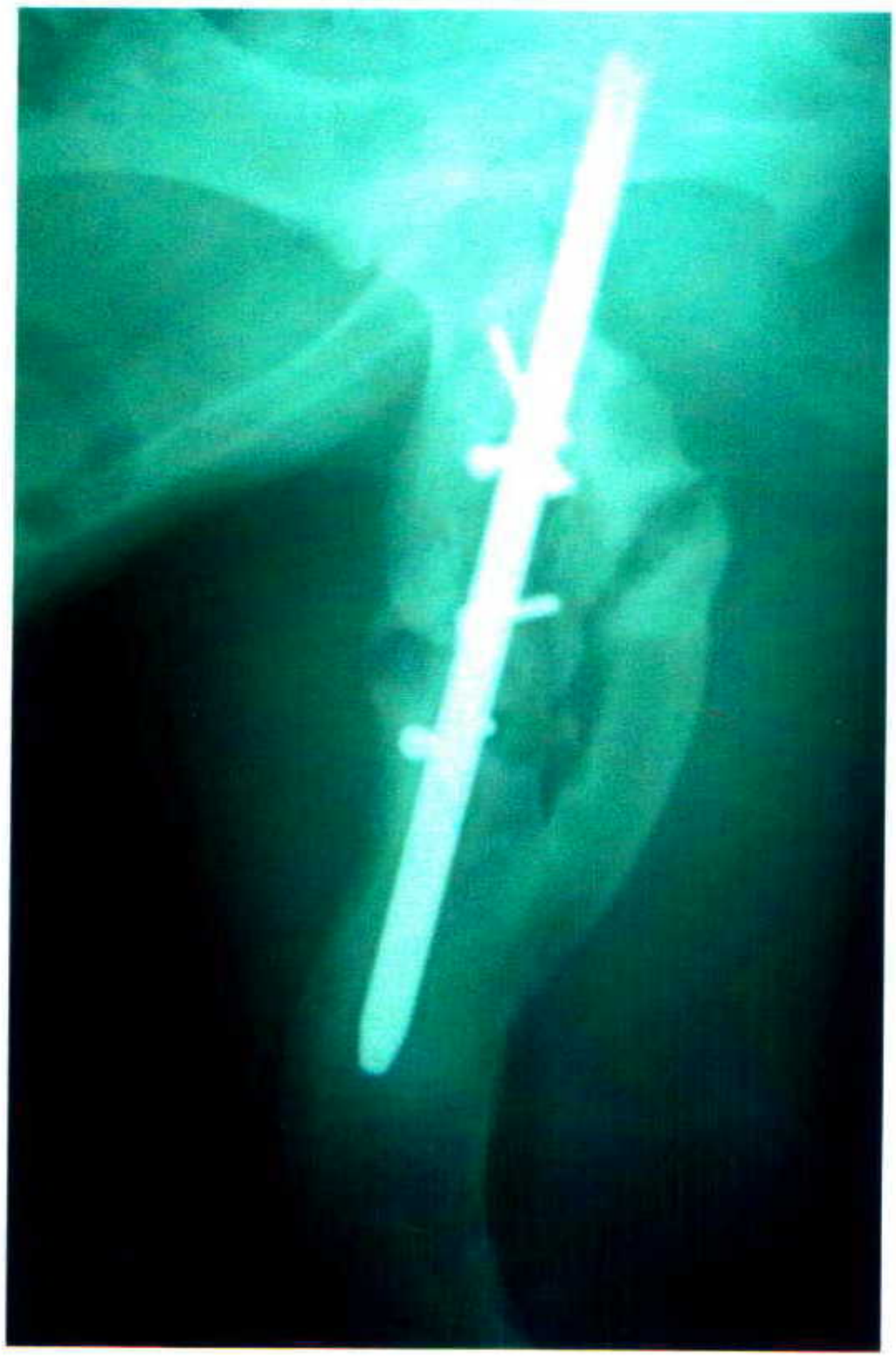


Fig. 65

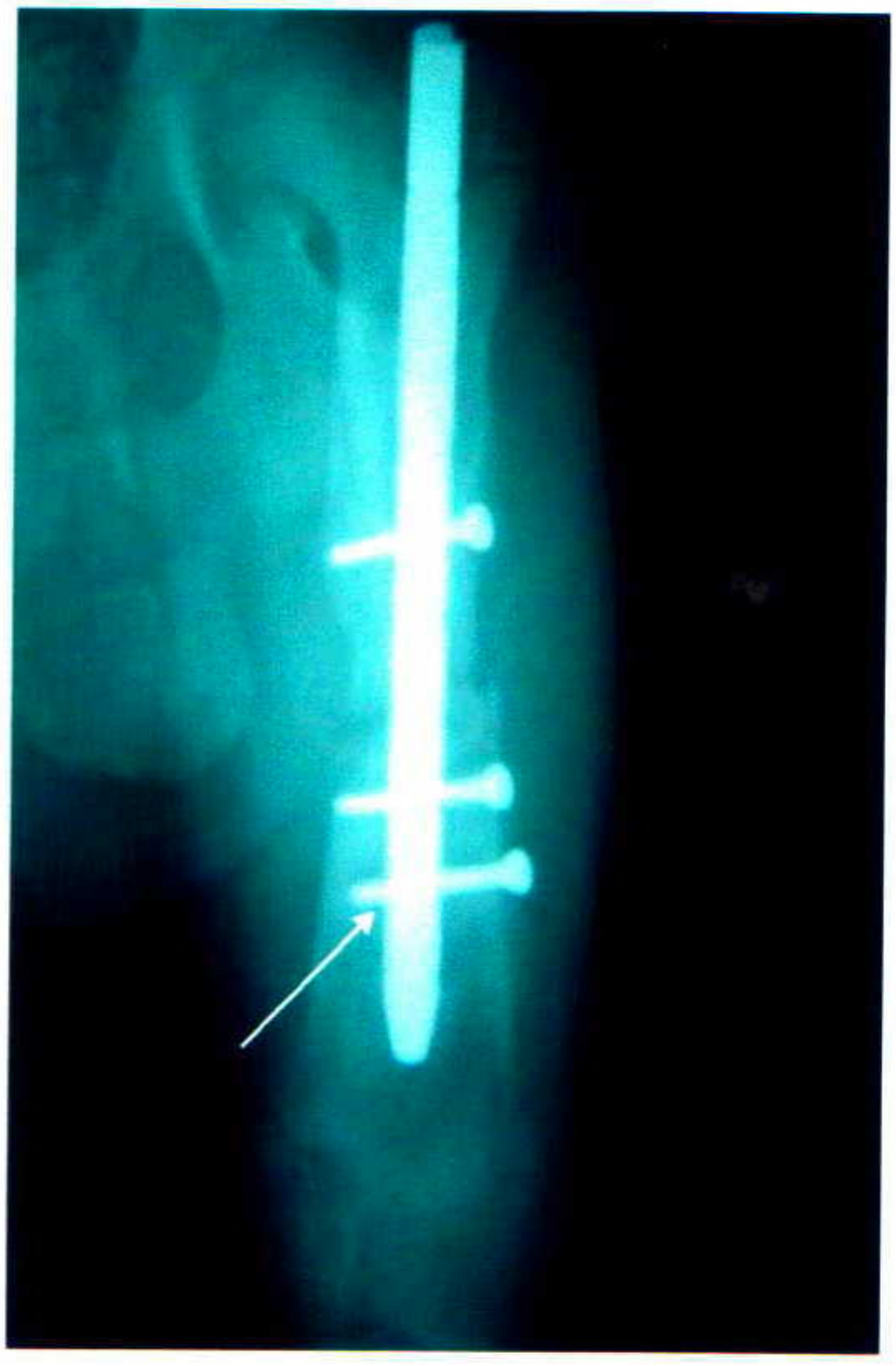


Fig. 66

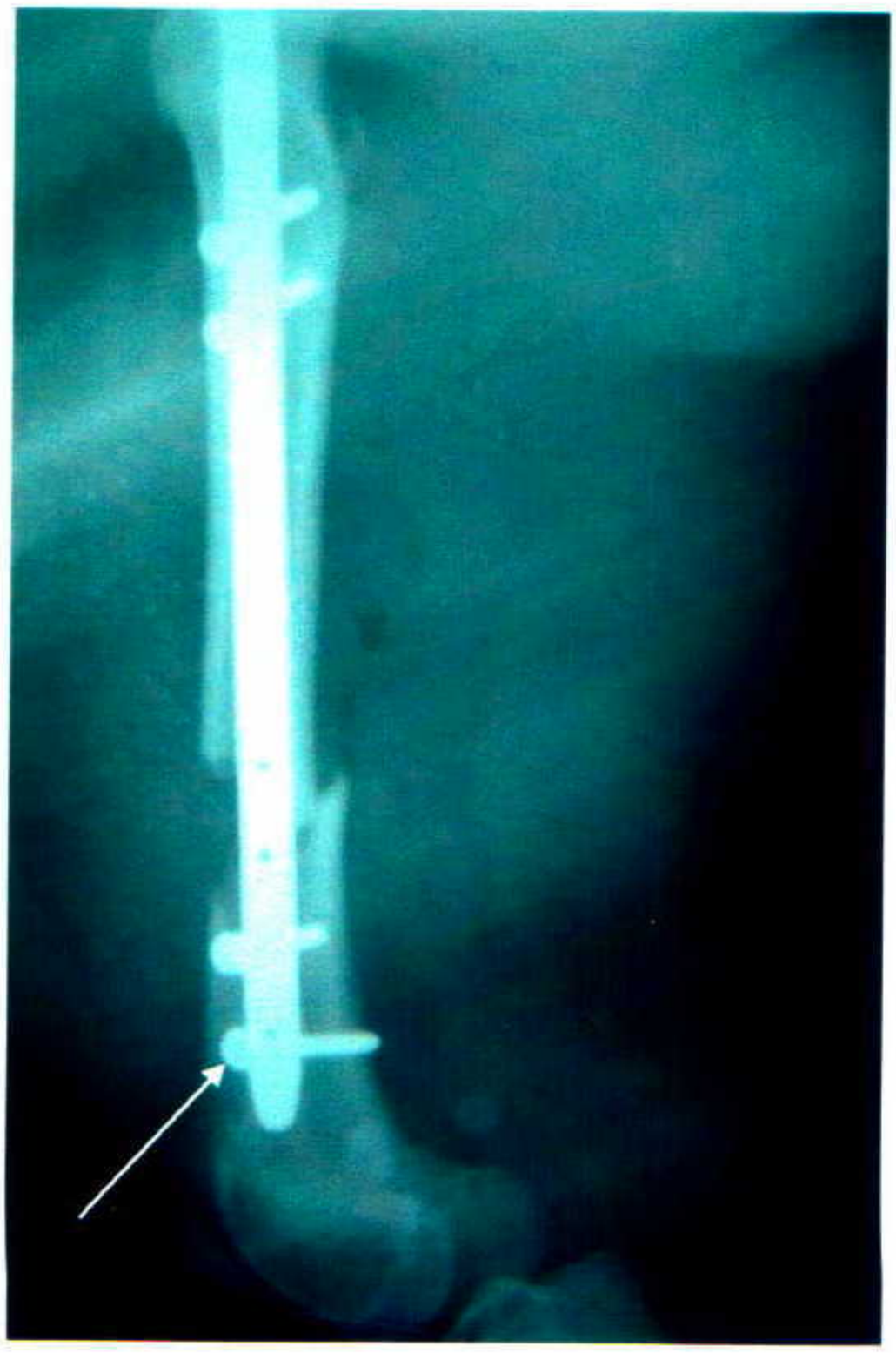


Fig. 67

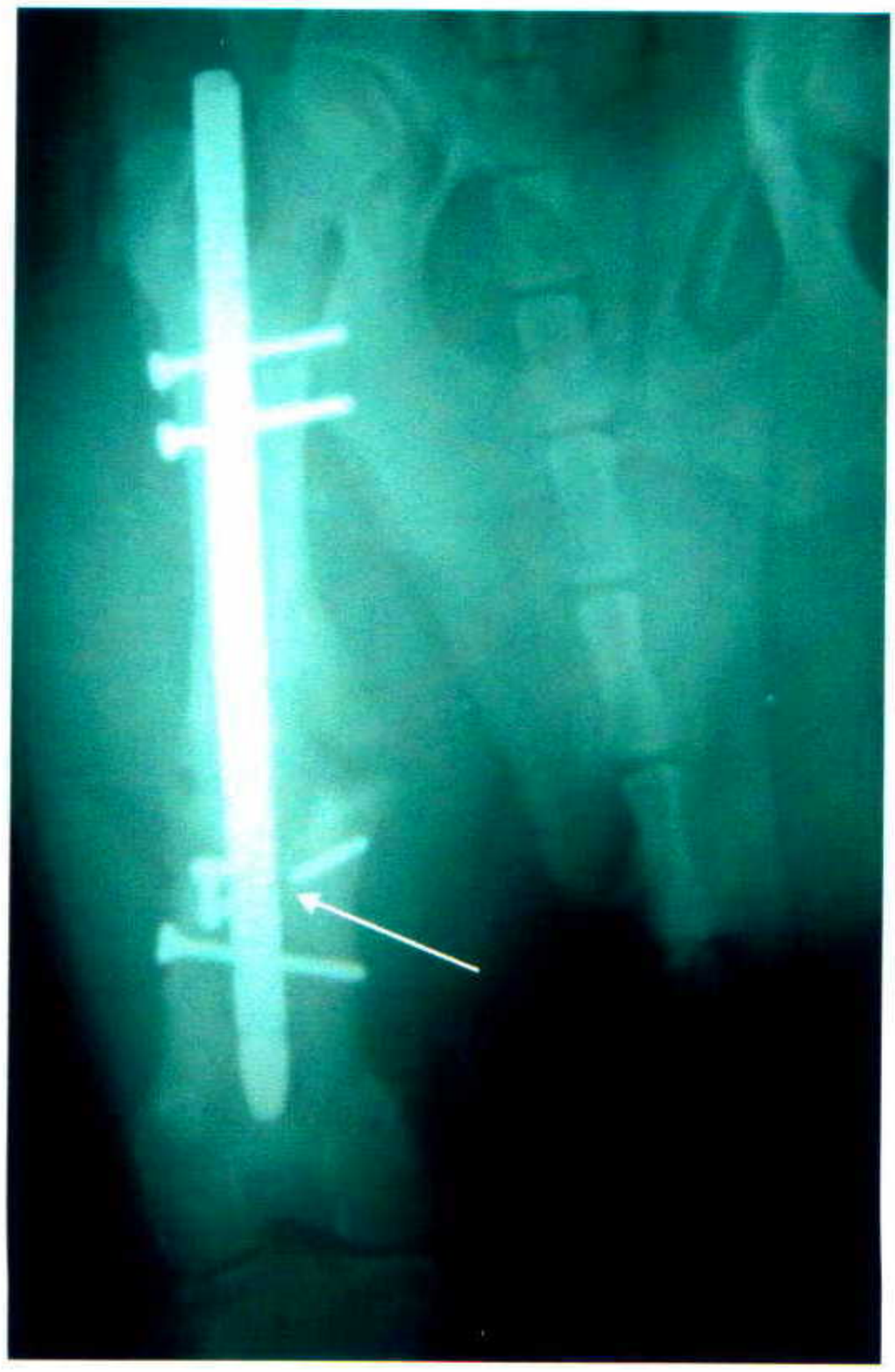


Fig. 68

radiograph revealed misdirected screws in the distal fragment (Fig 67). In dog 9, proximal of the two distal screws was broken (Fig 68). This dog had a distal femur fracture and proximal of the two distal screws was very close to fracture line.

Most complications related to distal screws namely, misdirected screws (n=3), screw bending (n=3) and screw breakage (n=3) were seen. The complications were seen mostly in 6 mm nail except for one case of screw bending and screw breakage in 8 mm nail (Table 20). Effect of reducing the screw diameter from 3.5 mm to 2.7 mm in 6 mm nail and 4.5 mm to 3.5 mm screw in 8 mm nail increased the fatigue life of nail by 52 and eight times respectively in nails (Dueland *et al* 1996) however, the smaller diameter transcortical screws allowed much retention of nails strength but themselves became weaker and hence were susceptible to fatigue failures.

No case of nail breakage was noticed. Similar results were seen by Raghunath (2002) during his study using IL nails.

In both the groups distal screw breakage and bending did not interfere with the clinical outcome and final limb usage in any of the case. The time for radiographic union was also comparable in both the groups suggesting that these complications did not affect the rate of fracture healing or the factors that affect the fracture healing. Screw breakage has been regarded as a common but much less serious complication in human patients. Similar results were seen in animals when breakage of screws offered no hindrance to fracture healing and

Table No 20: Distal Transcortical Screw Related Complication in Group I and Group II

S. No.	Type of Fracture	Complication	Group I		Group II	
			6mm	8mm	6mm	8mm
1.	Compd tibia oblique Fracture	Misdirected screw	✓			
2.	Simple femur oblique mid shaft fracture with few irreducible chips	Misdirected screw	✓			
3.	Simple femur transverse distal fracture	Distal screw bend then break	✓			
4.	Simple femur transverse distal fracture	Distal screw bend	✓			
5.	Simple femur segmental fracture, Distal fragment small	Distal screw bend		✓		
6..	Simple femur proximal subtrochanteric fracture	Proximal screw dislodged, Proximal distal screw break				✓
7.	Simple femur mid shaft transverse interdigitated fracture	Distal of the two distal screws back out from far cortex			✓	
8.	Simple femur distal 3rd fracture	Misdirected screw			✓	
9.	Simple femur distal 3rd fracture	Proximal of the two distal screw break			✓	

final out come. The chance of screw bending and screw breakage was seen more in cases with distal femur fractures in both the groups whether a single or more than one distal transcortical screw was used. In these cases the distal screw was found to be close to the fracture line or site. This screw related complication could be attributed to the deviation from the suggested recommendation made by Dueland *et al* (1996) in which he opined that the proximity of the screws to the fracture site in the distal fragment can affect the fatigue strength of implant near the fracture site.

From results it was also evident that the chance of distal screw related complications were more when the fractures were below mid shaft or low distal fractures. However, such complications did not affect the rate of fracture healing. Use of one distal transcortical screw provided adequate fracture stability for healing that was comparable to the stability provided by more than one distal transcortical screw. However, the implant stability was seen more when more than one distal transcortical screw was used in an 8 mm nail.

Chapter V

SUMMARY AND CONCLUSIONS

The present study was conducted on 21 long bone fractures in 19 clinical cases of dogs presented to Small Animal Clinics, Punjab Agricultural University, Ludhiana. The study included diaphyseal fractures of the femur, tibia and humerus, which were treated by static intramedullary IL nailing. The study was aimed to evaluate and compare the clinical efficacy of fixation modality with respect to use of distal transcortical screws in the distal fragment of the fractured bone.

During the study period, fractures of femur were found to be most common (n=16) followed by tibia (n=3) and humerus (n=2). Left limb was involved in (n=12) cases. Males (n=15) had more fractures than the females (n=4). Among various breeds German shepherd dogs (n=8) had highest number of the long bone fractures. The automobile accident was found to be main cause of trauma leading to fractures in dogs. Fractures were most common in dogs less than 1 year of age (n=10). Heavy dogs with b.w. 20 kg or more had highest number of long bone fractures (n=11).

The cases were divided into two groups and in Group I static intramedullary IL nailing was done with one transcortical screw placed in the distal fragment of the fractured bone and in Group II static intramedullary IL

nailing was done with more than one transcortical screw placed in the distal fragment of the fractured bone. In both the groups, 6 and 8 mm diameter nails of lengths 12, 14, 16 and 18 cm were used. In 6 cases, full cerclage wire was used to stabilize the multifragmented fractures and to achieve anatomic reconstruction. In both the groups standard anaesthetic protocol was found to be free from complications. In both the groups standard surgical approaches for long bone fractures proved effective for sufficient exposure for the placement of the distal screws. Intraoperative fracture reduction and stability was satisfactory in both the groups irrespective of the number of screws used in the distal fragments. The fixation modality was effective for wide range of fractures. Modified Robert John bandaging provided good joint immobility post operatively. The common antibiotic protocol of ampicillin, cloxacillin and gentamicin provided effective blanket against post operative infections in most of the cases. Weight bearing and limb usage was satisfactory in both the groups. Dogs could walk with their complete paw touching the ground in both the groups at around 10^{th} post operative day. Clinical outcome was excellent in dogs treated with this modality irrespective of the number of screws used in distal fragment of fracture except one case in group I in which limb usage was rated as fair due to lameness associated with osteomyelitis and one dog in group II, in which the limb usage was rated as poor due to collapse of the fracture fragments due to loss of reduction. In another dog of group II, the final outcome was rated as good. Complications like joint stiffness, muscle

atrophy, rotational deformity and limb shortening were not seen in any case in Group I and II.

Haematological parameters remained within the normal range in both the groups and followed the normal pattern of inflammatory process with transient leucocytosis.

Immediate post operative radiograph in both the groups revealed satisfactory fracture stability. Periosteal reaction was evident in both the groups around 10^{th}-15^{th} post operative day. Signs of bridging callus were evident in both the groups around 30-90^{th} post operative day radiograph. The time of radiographic union was comparable in both the groups. In group I, the mean time of radiographic union was 12.66 weeks. In group II, the mean time for radiographic union was 10.72 weeks. In one dog of group I, osteomyelitis was evident at 4 month in the post operative radiograph. At 6 month post operative radiograph osteolytic changes were present with extensive bone loss from the caudal aspect of the involved bone however the implant was stable and clinical outcome at this stage was rated fair. In group II, one dog revealed loss of fracture reduction due to collapse of the implant in both the limbs 1 month post operatively. This suggested that in bilateral fractures progressive weight bearing should be allowed till the radiographic signs of bone union were evident. In one dog with bilateral femur fracture in group II, osteomyelitis was seen in the right limb at 4 month post operative radiograph. The clinical outcome at this stage was rated good in this dog.

There was no case of nail breakage or bending in entire series in both the groups. The screw related complications such as misdirected distal screws (n=3), screw bending (n=3), screw dislodgement (n=3) and screw breakage (n=3) were seen. These were seen more often in cases where a 6 mm nail was used except for one case of screw bending and screw breakage and one screw dislodgement in an 8 mm nail. The screw related complication were seen more frequently in cases where a 6 mm nail was used in a distal fracture irrespective of the number of transcortical screws in the distal fragment. An 8 mm nail with more than one transcortical screw in the distal fragment had less chances of screw bending and screw breakage as compared to 6 mm nails. Chance of screw breakage or bending was most common in the proximal of the distal screws or the single distal screw which was close to the fracture line.

However these complications did not affect the fracture healing and clinical outcome. But a further study on the biomechanical properties of different types of screws is required to overcome these complications to guarantee better implant stability during the convalescent period.

In 5 cases of group II, the nail was removed. In one dog of group II, the extensive callus hindered location of screws. In another dog of this group, in which the nail was found to be embedded in the trochanteric fossa due to rapid growth gained by dog during convalescent period difficulty was experienced during removal of the nail. In yet another case of this group, the screws got broken during retrieval and these screws were removed from the nail holes by

inserting the drill bit in the hole and toggling the nail inside the medullary after attaching it to the extension rod.

The dogs in which the nails were removed had no clinical complication and in cases in which the nails were left *in situ* also had excellent clinical outcome suggesting that nail retrieval may be optional.

Conclusions

On the basis of the results of this study following conclusions are drawn:

1. Static intramedullary IL nailing is satisfactory fracture fixation modality and offers quick rehabilitation of the affected dogs, with very good clinical outcome and high success rate. It also offers free range of motion of the joints of the affected limbs.
2. Where ever possible in distal fractures or fractures that are below mid shaft, larger diameter nail should be used to avoid toggling of the nail in the distal fragment of the fractured bone, which leads to screw related complications and more than one distal transcortical screws should be used which affords better implant stability.
3. The technique warrants instrument precision like sharp drill bits and taps to overcome complications such as misdirected screws.

4. Interlocking nailing could be used successfully to treat comminuted and rotationally unstable fractures of long bones. Their role in the internal fixation can be successfully expanded to bilateral femur fractures and fractures with extensive bone loss.
5. Distal transcortical screw related complications are more than the proximal transcortical screw related complications however these complications seldom affect the clinical outcome of this fracture fixation modality.

REFERENCES

Adil Y (2001) *Studies on the comparison of intramedullary cross pinning and Intramedullary stacked pinning for prevention of axial rotation in femur fractures in dogs.* MVSc thesis Punjab Agricultural University, Ludhiana India.

Aithal H P and Singh G R (1999) Pattern of bone fractures caused by road traffic accidents and falls in dogs: A retrospective study. *Indian J Anim Sci* **69:** 960-61.

Alho A, Stromsoe K and Eklamd A (1991) Locked intramedullary nailing of femoral shaft fractures. *J Trauma* **31**: 49-59.

Aper RI, Litsky A S, Roe S C and Johnson K A (2003) Effect of bone diameter and eccentric loading on fatigue life of cortical screws used with interlocking nails. *Am J Vet Res* **64**: 569-73.

Arnoczky S P, Wilson J W and Schwarz P (1985) Fractures and fracture Biology In: Slatter D H (ed) *Textbook of small animal surgery* PP 1939-45 P. A Saunders Philadelphia.

Axelson P, Raiha J, Mero M, Vanionpaa S, Tormala P and Rokkanen P (1988) The use of biodegradable implant in fracture fixation : A review of the literature and a report of two clinical cases. *J Small Animal Prac* **29**: 249-55.

Bains S S (2000) *Comparative evaluation of cross pinning, intramedullary cross pinning and intramedullary retrograde pinning for management of supracondylar fracture of femurs in dogs.* MVSc thesis Punjab Agricultural University Ludhiana India.

Balagopalan TP, Devanand CB, Rajankutty K, Sarada Amma T, Raveeendran S, Abraham V C, Jalaluddin A M, Muraleedharan Nayar K N and George P O (1995) Fractures in dogs – A review of 208 cases. *Indian J Vet Surg* **16**: 41-43.

Barnhart M (2000) Technical note on interlocking nailing in canines: *Handbook of canine orthopedics*. Columbia Emergency Veterinary Practice.

Benirschke S K, Meldar I, Henley M B, Routt M L, Smith D L, Chapman J R and Ontkowski M F (1993) Closed interlocking nailing of femoral shaft fractures: assessment of technical complications and functional outcomes by comparison of a prospective database with retrospective review. *J Orthop Trauma* 7: 118-22.

Bernarde A, Diop A, Maurel N and Eric V (2001) An *in vitro* biomechanical study of bone plate and interlocking nail in a canine diaphyseal femoral fracture model *Vet Surg* **30** : 397-408.

Bohm P, Scherer M A, Fruh H J, Ascherl R and Motzer E (1995) Experimental studies of the biomechanical properties of the hollow nails and solid nails for interlocking intramedullary nailing in the dog. *Biomed Tech* **40**: 24-28. (Original not seen. Abstr in PubMed Abstracts PMID: 7703346)

Bone L B and Johnson K D (1986) Treatment of tibial fractures by reaming and intramedullary nailing. *J Bone Joint Surg* **76**: 877-87.

Boone E G, Johnson A L and Hohn R B (1986) Distal tibial fractures in dogs and cats. *J Am Vet Med Assoc* **188**: 36-40.

Bostman O, Varjonen L, Vainionpaa S, Majola A and Rokkanen P (1989) Incidence of local complications after intramedullary nailing and after plate fixation of femoral shaft fractures. *J Trauma* **29**: 639-45.

Boyer I M, Ribeiro E and Powell J N (1996) Small versus large diameter closed section femoral nails for the treatment of femoral shaft fractures: Is there a difference? *Injury* **41**: 279-82.

Branden T D, Eicker S W, Adinoor D and Pieur W D (1995) Characterstics of 1000 femur fractures in the dog and cat. *Vet Comp Orthop Traumatol* **8**: 203-09.

Brumback R J, Uwagie- Ero S, Laktos R P, Poka A, Bathon G H and Burgess A R (1988) Intramedullary nailing of femoral shaft fractures. *J Bone Joint Surg* **70**:1453-62.

Brumback R J, Toal T R, Murphy- Zane M S, Novak V P and Belkoff S M (1999) Immediate weight bearing after treatment of a comminuted fracture of the femoral shaft with a statically locked intramedullary nail. *J Bone Joint Surg* **81**: 1538-44

Brumback RJ, Ellison T S, Poka A, Lakatos R, Bathon G H and Burgess A R (1989) Intramedullary nailing of open fractures of femoral shaft. *J Bone Joint Surg* **71**: 1324-31

Brumback RJ, Ellison T S, Poka A, Lakatos R, Bathon G H and Burgess A R (1992) Intramedullary nailing of femoral shaft fractures Part III: Long term effects of static interlocking fixation. *J Bone Joint Surg* **74**: 106-12

Bucholz R W, Ross S E and Lawrence K L (1987) Fatigue fractures of the interlocking nail treatment of fractures of distal part of the femoral shaft. *J Bone Joint Surg* **69**: 1391-99.

Church E M and Schrader S C (1990) Use of flexible intramedullary rods for fixation of femoral fractures in eight dogs. *J Am Vet Assoc* **196**: 71-76.

Colchero F, Orst G, Reboul C, Villalobos F and Vidal J (1983) Intramedullary locking nailing. Experimental study. Surgical Technique. Results. *Rev Chir Orthop Reparatrice Appar Mot* **69**:547-55 (Original not seen. Abstr in PubMed Abstracts PMID: 6228985)

Dallman M J, Martin R A, Self B P and Grant J W (1990) Rotational strength of double pinning techniques in repair of transverse fractures in femurs in dogs. *Am J Vet Res* **51**: 123-27.

Dueland R T, Berglund L, Vanderby R and Chao E Y S (1996) Structural properties of interlocking nails, canine femora and femur interlocking constructs. *Vet Surg* **25**: 386-96.

Dueland R T, Johnson K A, Roe S C, Engen M H and Lesser A S (1999) Interlocking nail treatment of diaphyseal long bone fractures in dogs. *J Am Vet Med Assoc* **214**: 59-65.

Duhautois B (1995) Interlocking pin fixation in veterinary surgery. Retrospective clinical study on 45 cases. *Clinique Veterinaire Saint- Maur* **30**: 613-30 (Abstr).

Duhautois B (2001) Interlocking nail treatment in dogs and cats: a retrospective study about 121 from 1992-1999 *Pratique- Medicale- Chirurgicale-de-Animal-de-Compagnie* **36**: 481-496 (Original not seen Abstr in PubMed Abstracts PMID: 12520485).

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

Durall I and Diaz M C (1996) Early experience with the use of an interlocking nail for the repair of canine femoral shaft fractures *Vet Surg* **25**:397-406.

Durall I, Diaz M C and Morales I (1993) An experimental study of compression of femoral fractures by an interlocking intramedullary pin. *Vet Comp Orthop Traumatol* **6**: 93-99.

Durall I, Diaz M C and Morales I (1994) Interlocking nail stabilization of humeral fractures. Initial experience in seven clinical cases. *Vet Comp Orthop Traumatol* **4**:28-34.

Durall I, Diaz M C, Puchol J L and Franch J (2003) Radiographic finding related to interlocking nailing: windshield –wiper effect and locking screw failure. *Vet Comp Orthop Traumatol* **16**: 217-22

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. *J Vet Med Sci* **60** :119-112.

Eveleigh R J (1995) A review of biomechanical studies of intramedullary nails. *Med Eng Phys* **17**: 323-31.

Fox S M, Bray J C, Guerin S R and Burbridge H M (1995) Antebrachial deformities in the dog: treatment with external fixation. *J small Anim Pract* **36**: 315-320.

Georgiadis G M, Minster G J and Moed M R (1990) Effect of dynamization after interlocking tibial nailing: an experimental study in dogs. *J Orthop Trauma* **4**: 323-30.

Glennon J C, Flanders J A, Beck K A, Trotter E J and Erb H N (1994) The effect of long term bone plate application for fixation of radial fractures in dogs. *Vet Surg* **23** : 40-7.

Grono L R (1964) Treatment of femoral fractures in dogs. *Aust Vet J* **40**: 172-76.

Grover J and Wiss D A (1995) A prospective study of fractures of femoral shaft treated with a static intramedullary interlocking nail comparing one versus two distal screws. *Orthop Clin North Am* **26**: 139-46

Hajek P D, Bicknell H R, Bronson W E, Albright J A and Saha S (1993) The use of one compared with two distal screws in the treatment of femoral shaft fractures with interlocking nailing. *J Bone Joint Surg* **75**: 519-25.

Hauschild G and Fehr M (1999) Biological osteosynthesis by interlocking nailing in dogs. *Tierarzliche- Praxis* **27**: 356-63.

Hunt J M, Aitken M L, Denny H R and Gibbs C (1980) The complications of diaphyseal fractures in dogs: A review of 100 cases. *J Small Anim Pract* **21**: 103-119.

Johnson K D and Tencer A (1990) Mechanics of intramedullary nails for femoral fractures. *Unfallchirurg*: **93**: 506-11.

Kempf I, Grosse A and Beck G (1985) Closed locked intramedullary nailing- Its application to comminuted fractures of the femur. *J Bone Joint Surg* **67**: 709-20.

Klein M P, Rahn B A, Frigg R, Kessler S and Perren S M (1990) Reaming versus nonreaming intramedullary nailing: interference with cortical circulation of the canine tibia. *Arch Orthop Trauma Surg* **109**: 314-16 (Original not seen. Abstr in PubMed Abstracts PMID: 2073449, 1990)

Knecht C D, Allen A R, William D J and Johnson J H (1987) *Fundamentals techniques in veterinary surgery* 3rd edn PP 228-29, 322-23. W.B Saunders, Philadelphia.

Kolata R J, Kraut N H and Johnson D E (1975) Patterns of trauma in urban dogs and cats: a study of 1000 cases. *J Am Vet Med Assoc* **164**: 499-502

Kyle R F (1985) Biomechanics of intramedullary fracture fixation. *Orthopedics* **8**: 1356-9.

Langley Hobbs SJ and friend E (2002) Interlocking nail repair of a fractured femur in a turkey. *Vet Rec* **150**: 247-48.

Larin A, Eich C S, Parker R B and Stubbs W P (2001) Repair of diaphyseal femoral fractures in cats using interlocking intramedullary pins: 12 cases (1996-2000). *J Am Vet Med Assoc* **219**: 1098-1104.

Larsson S, Kim W, Caja V L, Egger E L, Inoue N and Chao E Y (2001) effect of early axial dynamization on tibial bone healing: a study in dogs. *Clin Orthop* **388**: 240-51.

Lin J, Hou S M and hang Y S (2000) Treatment of humeral shaft delayed unions and non unions with humeral locked nails. *J Trauma* **48**: 695-703.

Lin J, Lin S J, Chen P Q and Yand S H (2001) stress analysis of the distal locking screws for femoral interlocking nailing. *J Orthop Res* **19**: 57-63.

Lorinson D, Grosslinge K and Vidoni B (2000) Interlocking nail application to long bone fractures in dogs and cats. *Wiener- Tierarztliche- Monatsschrift* **87**: 278-83 (Abstr.).

Maala C P and Celo E M (1975) A study on the anatomical locations incidence and causes of fractures in dogs. *Phillipine J Vet Med* **14**: 137-43.

Mahajan S K (1998) *Studies on the evaluation of the fixation techniques for supracondylar fracture of femur in dogs*. MVSc thesis Punjab Agricultural University Ludhiana India

McClure S R, Watkins J P and Ashman R B (1998) *In vivo* evaluation of intramedullary interlocking nail fixation of transverse femoral osteotomies in foals *Vet Surg* **27**: 29-36

McDuffee L A, Stover S M, Taylor K T and Les C M (1994) An *in vitro* biomechanical investigation of an interlocking nail for fixation of diaphyseal tibial fracture in adult horses. *Vet Surg* **23**: 219-30

McLaughlin R M and Roush J K (1999) Repairing fractures with bone plates and screw fixation. *Vet Med* **94**: 64-73

Medoff R J (1986) Insertion of the distal screws in interlocking nail fixation of femoral shaft fractures: Technical Note. *J Bone Joint Surg* **68**: 1275-77.

Miller C W, Sumner-Smith G, Sheridan C and Pennok P W (1998) Using unger system to classify 386 long bone fractures in dogs. *J Small Anim Prac* **39**:390-93.

Moses P A, Lewis D D, Lanz O I, Stubbs W P , Cross A R and Smith K R (2002) Intramedullary interlocking nail stabilization of 21 humeral fractures in dogs and one cats. *Aust Vet J* **80**: 336-43

Muir P and Johnson K A (1996) Interlocking intramedullary nail stabilization of a femoral fracture in a dog with osteomyelitis. *J Am Vet Med Assoc* **209**: 1262-64

Nunamaker D M (1985) Methods of internal fixation: Newton C D and Nunamaker D M (ed) *Textbook of small animal orthopedics* PP 252-53, 263-66. J B Lippincott, Philadelphia.

Parker R B and Bloomberg M S (1984) Modified intramedullary pin technique for repair of distal femoral physeal fractures in the dog and cat. *J Am Vet Med Assoc.* **184**: 1259-65

Patil D B, Jani B M, and Parsania R R (1991) A note on the incidence of fractures in animals: 10 year survey. *Indian J Vet Surg* **12**: 126

Phillips I R (1979) A survey of bone fractures in the dogs and cats. *J Small Anim Prac* **20**: 661-74

Piermattei D L and Greeley R G (1979) *An atlas of surgical approaches to the bones of dogs and cats*. 2nd edn PP 162-63. W. B Saunders Philadelphia.

Presnell K R (1978) Pin versus plates: The orthopedic dilemma. *Vet Clin North Am Small Anim Prac* **8**: 213-17

Radcliffe R M, Lopez M J, Turner T A, Walking J P, Radcliffe C H and Markel M D (2001) An *in vitro* biomechanical comparison of interlocking nail constructs and double plating for fixation of diaphyseal femur fractures in immature horses. *Vet Surg* **30**: 179-90.

Raghunath M (2002) *Studies on intramedullary interlocking nailing and dynamic compression plating in long bone fracture fixation in dogs.* PhD thesis Punjab Agricultural University, Ludhiana India

Raghunath M and Singh S S (2002) Intramedullary interlocking nails for long bone fracture fixation in dogs using indigenously designed equipment. *Indian J Vet Surg* **23**: 89-91.

Ramon A J, Santoscoy C, Garcia G A, Aluja A S, Constantino C F, Arzate B A, Gracia R, Roslies M R and DeAluja A S (1996) Comparative studies on bone tissue submitted to compression and fixation with metals plates in humans and dogs. *Veterinaria Mexico* **27**:57-61.

Rand J A, An K N, Chao E Y S and Kelly P J (1981) A comparison of the effect of open intramedullary nailing and compression plate on fracture- site blood flow and fracture union. *J Bone Joint Surg* **63**: 427-42.

Reikeras O (1987) Cardiovascular reactions to intramedullary reaming of long bones in dogs. *Acta Anaesthesiol Scand* **31**: 48-51.

Roush J K (1998) Fracture management: Part I. *Vet Med* **98:** 1063

Roush J K and McLaughlin R M (1998) Fundamentals of fracture management.. *Vet Med* ***98****:1065*-70.

Roush J K and McLaughlin R M (1999) Using interlocking nail fixation to repair fractures in small animals. *Vet Med* **94**: 46-50.

Sancineto C F, Rubel I F, Seligson D and Ferro G V (2001) Technique for removal of broken interlocking screws. *J Orthop Trauma* **15**: 132-34

Sastry G A (1998) *Veterinary Clinical Pathology* pp 1-25 CBS Publishers and Distributers Pvt Ltd,. Delhi.

Sedel L, Christel P, Dewas J and Leray J. (1979) The mechanical properties of callus in fractures treated by nailing or plating: an experimental study. *Rev Chir Orthop Reparatrice Appar Mot* **65**:165-74.

Singh M , Nigam J M, Sharma S K, Varshney A C and Kumar V (1999) Incidence of fractures in canines and their management. *Indian Vet J* **76**: 922-23.

Suber J T, Basinger R R and Keller W G (2002) Two unreported modes of interlocking nail failure: breakout and screw bending. *Vet Comp Orthop Traumatol* **15**: 228-32.

Tamas P M, Paddleford R R and Krahwinkel DJ Jr. (1985) Thoracic trauma in dogs and cats for limb fractures. *J Am Anima Assoc* **21**: 161-166.

Tanna D D (1993) Interlocking tibial nailing without an image intensifier. *J Bone Joint Surg* **76**: 670.

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

Trostle S S, Wilson D G, Dueland R T and Markel M D (1995) *In vitro* biomechanical comparison of solid and tubular interlocking nails in neonatal bovine femur. *Vet Surg* **24**: 235-43.

Uta S (1992) A new intramedullary nailing system for long bone fractures – biomechanical evaluation and animal study of a new intramedullary nail *Nippon Seikeigeka Gakkai Zasshi* **66**: 907-18 (Original not seen Abstr in PubMed Abstracts PMID: 1447525).

Wang X, Mabrey J D and Agarwal C M (1998) An interspecies comparison of bone fracture properties. *Biomed Mater Eng* **8**: 1-9

Widjaja W and Hartung C (2001) Biomechanical comparison of different fixations of femur interlocking nails. *Clin Biomech* **16**: 702-5.

Winquist R A, Hansen S T and Clawson D K (1986) Closed intramedullary nailing of femoral fractures. *J Bone Joint Surg* **66**: 529-39.

Wiss D A, Brien W W and Becker V (1991) Interlocking nailing for the treatment of femoral fractures due to gunshot wounds. *J Bone Joint Surg* **73:**598-606.

Wolinsky R P, McCarty E, Shyr Y and Johnson K (1999) Reamed intramedullary nailing of the femur: 551 cases. *Injury, Infection and Critical Care* **46**:392-98

Wong W T (1984) A survey of fractures in the dogs and cats in Malaysia. *Vet Rec* **115**: 273-4.

Wu C C and Shih C H (1993) Segemental tibial shaft fractures treated with interlocking nailing. *J Orthop Trauma* **7**: 468-72.

Yokoyama K, Itoman M, Shindo M, Kai H, Veta S and Kobayashi A (1999) Deep infection and fracture healing in immediate and delayed locked intramedullary nailing for open femoral fractures. *Orthopedics* **22** : 485-90

Zaal M D, Hazewinkel H a (1996) Classification of 202 tibial fractures in dogs and cats. *Tijdschr Diergeneeskd* **121**:218-23 (Original not seen Abstr in PubMed Abstracts PMID: 8669052).

Zuckerman JD, Veith R G, Johnson K D, Bach A W, Hansen S T and Solvik S (1981) Treatment of shaft fractures with closed interlocking intramedullary nailing. *J Orthop Trauma* **1**: 201-208

VITA

Name of the student	:	**Manpreet Singh**
Father's name	:	Mr. Harparkash Singh
Mother's name	:	Mrs. Nirmal Kaur
Nationality	:	Indian
Date of birth	:	26-10-1979
Permanent home address	:	10-I, Sarabha Nagar Ludhiana – 141 001, Punjab, India.

EDUCATIONAL QUALIFICATION

Bachelor degree	:	B.V.Sc. & A.H.
University and year of award	:	Punjab Agricultural University, Ludhiana, 2002.
OGPA/OCPA/% marks	:	8.06/10
Master's degree	:	M.V.Sc. (Surgery & Radiology)
University and year of award	:	Punjab Agricultural University, Ludhiana, 2004.
OGPA/OCPA/% marks	:	8.26/10

Award/Distinctions/Fellowships/ Scholarships :

- ❖ University merit scholarship in 1st and 2nd semesters, 1998-99, 99-2000.2000-2001, 2001-2002 during B.V.Sc. & A.H.
- ❖ Merit certificate in B.V.Sc. & A.H.
- ❖ Merit certificate in M.V.Sc
- ❖ University merit scholarship for M.V.Sc