

# MANAGEMENT OF OLECRANON FRACTURE IN DOG



## Thesis

SUBMITTED IN PARTIAL FULFILMENT OF  
THE REQUIREMENTS FOR THE DEGREE

OF

**Master of Veterinary Science**

IN

**DIVISION OF SURGERY**

BY

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TO

DEEMED UNIVERSITY

INDIAN VETERINARY RESEARCH INSTITUTE

IZATNAGAR - 243122 (U.P.), INDIA

**1997**

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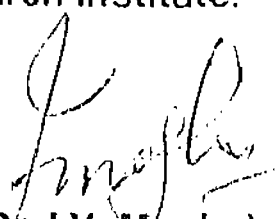
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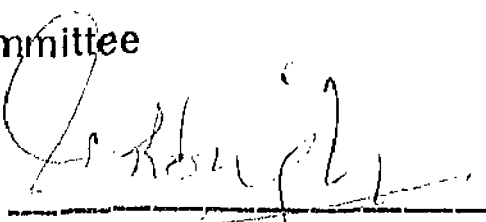
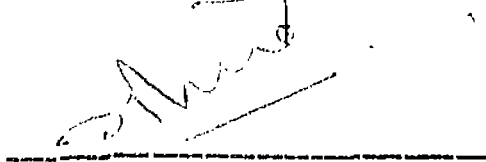
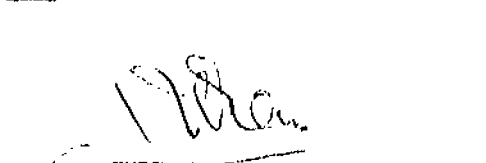
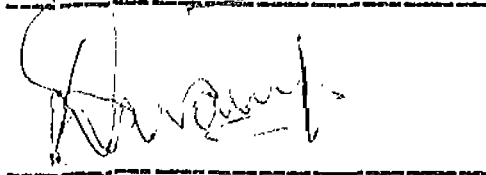
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*Dedicated to all those animals who suffered  
for the cause of science*

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## ACKNOWLEDGEMENTS

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I take this unique opportunity to acknowledge my deep sense of gratitude to **Dr. I.V. Mogha**, senior scientist, chairman of the advisory committee, Div. of Surgery for his valuable guidance, keen interest and constructive criticism throughout the period of my work. His fatherly affection and constant support will always be remembered by me.

I am honoured by working under competent supervision of **Dr. Gajraj Singh**, senior scientist, Div. of Surgery. The knowledge gained from him in terms of surgical techniques, research, teaching and humanity will always be a great help to me.

I am highly obliged to **Dr. Amar Pal**, scientist, Division of Surgery, **Dr. D. Swaroop**, senior scientist, Division of Medicine and **Dr. Ram Kumar**, senior scientist Division of Pathology, the learned members of my advisory committee for their genuine help and expert suggestions throughout my work.

With respect I thank to the Director and the Joint Director (Academic) IVRI, for providing the necessary facilities to complete this work and financial assistance in the form of junior research fellowship.

Words are just inadequate in acknowledging the unparalleled help, constant encouragement and moral boosting by **Dr. H.P. Althal**, scientist, Division of Surgery throughout my study and work period. His exemplary hard working, sincere and humble nature always kept my spirit high.

I wish to express my heartiest thanks to **Dr. O.P. Gupta**, **Dr. K. Pratap**, **Dr. A.K. Sharma**, **Dr. Naveen Kumar**, **Dr. M. Hoque**, **Dr. Prakash**, **Dr. A. Pawde**, **Dr. S.K. Maiti**, Division of Surgery and **Dr. Sai Kumar**, Division of Pathology for their help in many ways.

The technical assistance and co-operation provided by **Mr. H.C. Setla**, **Mrs. A. Lakshmanan**, **Mr. Shekhar** and **Mr. Pandey** are gratefully acknowledged.

The spirited company of **Anjum**, **Sreekumar**, **Valbhav** and **Gautam** made my IVRI

stay, a beautiful experience of my life. No word can acknowledge their contribution to my life.

The unflinching support and help by my dear friends **Davender, Piyush, Keshav, Munish and Sethu** is gratefully acknowledged.

The help and support of scholars of surgery **Jitu, Apra, Deepali, Sujeet, Hansraj, Dinesh, Surjeet, Pankaj** and **Dr. Debaki Ghosh** is long remembered.

The friendship and cooperation of **Alok, Neelima, Utsav, Adi, Satish, Sreenu, Birader, Kamble, Karthikeyan, Ashok, Renji, Manju, Manisha, Gyanprabha** and **Zeba** was of great help to me.

My special thanks to my juniors **Puneet, Wasim** and **Karamveer** for their love and support.

I sincerely acknowledge the great care and affection of my senior **Dr. Gyanendra Singh** throughout my stay at Pantnagar as well as in IVRI, Izatnagar.

I sincerely thank to my long time friends **Devesh, Brejesh, Sandeep, Neelu, Malik** and **Richa** who are the constant source of inspiration and motivation throughout my academic career.

The neat typing and laser setting of **Bytes and Bytes**, Nehru Park Colony, Bly. is worth mentioning.

I express my heartfelt gratitude to my parents who taught me to believe in myself and to do my best. I owe immensely to my sisters for their affection and love.

Izatnagar

Date :4/12/96



**Som Prakash Tyagi**

# Introduction

# INTRODUCTION

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Fracture is one of the most commonly encountered surgical conditions in dog, usually resulting from automobile accidents or falling from height (Newton 1985). Treatment of fracture requires adequate fixation of fracture and subsequent proper management of animal. The management of epiphyseal and metaphyseal fractures is relatively more difficult due to certain associated complications during fracture fixation as well as afterwards. Olecranon fracture is one such type of fracture, whose management is a real challenge to veterinary surgeon. Though the incidence of olecranon fracture is low (Phillips, 1979), such fractures belong to a specific group of fractures 'The distracted fractures', which are characterized by the presence of gap between the two fractured fragments of bone due to the pull of attached tendon/muscle or ligament on one of the fragments. Such fractures require special attention and extra care for treatment and if not properly treated, may often result into delayed union/malunion resulting in improper limb function.

Many treatment modalities have been used for the repair of olecranon fractures in the past. O'connor (1950) opined that the prognosis of such fractures was unfavourable, if treated by conservative method of external immobilization alone as it is not sufficient to keep the fractured fragments in apposition. Therefore, utility of external fixation for olecranon fractures have been ruled out since long.

Single intramedullary steimmann pin in dog (Leonard, 1961), single rush pin in equines (Hickman 1964) and cat (Phillips, 1979), rush pin with tension band wire in dog (Phillips, 1979), tension band wiring with two Steinmann pins in dogs (Wolff, 1972), stainless steel plate on caudal and lateral aspects of ulna in canines (Denny, 1993) and equines (Scott 1975), single cancellous or cortical bone screws in dogs (Ormrod 1966, Neal 1981) and cancellous screw along with tension band wire in dog (Palmer, 1988) are few of the important techniques tried for repair of olecranon fractures in the past.

However, none of these techniques has been found suitable in all type of cases. Most of the techniques have been used in clinical cases and there was the lack of uniform fracture presentation in these cases. Since no definite conclusion could be drawn about the utility of these techniques for repair of olecranon fracture, a systematic comparative controlled study was designed with the following objectives -

(1) To standardise internal fixation techniques for the repair of olecranon fracture in experimental dogs.

(2) To evaluate and compare the efficacy of various internal fixation techniques for olecranon fracture repair in dogs.

Review  
of  
Literature

# REVIEW OF LITERATURE

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Fractures of either radius or ulna or both together accounted for approximately 18% of all the fractures in dog and cat (Phillips, 1979). In the fractures involving ulna, the fractures of proximal ulna were often encountered. The olecranon is the proximal extremity of ulna that serves as a lever for the triceps, the powerful extensor muscle of the elbow (Egger, 1985). Complete fracture of olecranon results in severe proximal displacement of the fractured fragment away from the ulna. This distraction of proximal fragment has to be corrected in order to achieve good bone healing. The prognosis of olecranon fracture has been reported to be unfavourable due to the problem of keeping the fracture fragments in apposition (O'Connor, 1950). Because external co-aptation is unable to control the distractive pull of triceps, open reduction and internal fixation was indicated for such fractures (Leonard, 1961). The different internal fixation techniques used for repair of olecranon fracture can be reviewed under following heads -

- 1- Intramedullary pinning
- 2- Tension band wiring
- 3- Stainless steel plating
- 4- Lag screw fixation.

## *INTRAMEDULLARY PINNING*

Ever since the first fracture management by intramedullary pin in dog by Knoll in 1943 (Brinker, 1983), this technique remained most popular and widely used technique in veterinary orthopaedics due to its simplicity in application. The Steinmann pin is the most commonly used pin which resists bending in all directions but has little resistance to rotation at the fracture site. (Denny, 1985). The common indication for its use is the transverse or little oblique fractures of long bones. Leonard (1961) opined that the fracture of ulna involving

the olecranon process could best be handled by intramedullary pinning. He reported two possible techniques ; one by inserting pin through a stab incision at the point of elbow and the other by open reduction and fixation. However, use of single intramedullary pin is not free from complications. Since, the ulna narrows rapidly in its distal part it is possible that the pin may be forced too far and cause damage to the distal end especially if larger diameter pin is used (Leonard 1961). Dingwall (1974) opined that fixation with a smooth intramedullary pin alone was inadequate as the proximal segment slid upwards and a gap developed at the fracture site resulting in a delayed or nonunion. Therefore additional external support is needed to keep the limb in extension. Alexander (1979) also reported failure of single intramedullary pin fixation in dogs in such fractures.

Rush pins have also been used for the treatment of olecranon fractures in equines (Hickman, 1964) and cat (Phillips, 1979). However, the disadvantages of single rush pinning remained same as that of the Steinmann pin. The fractured cortex adjacent to elbow joint act as a fulcrum over which the pin might be bent by the powerful pull of the triceps muscles (Denny, 1993). The narrow diameter of the shaft of ulna also limited the holding power of the pin.

### ***TENSION BAND WIRING***

The tension band wiring employs the tension band principle of physics by which a compression vector can be created from two distracting forces (Higdon, 1966). The utilization of this principle in orthopaedics is aimed to provide rigid fixation and thus, to promote primary bone healing (Mullar, 1970). Pauwels (1965) described a simple method of interfragmentary compression by wiring employing the tension band principle. In man, the wire tension band became popular mainly for the treatment of avulsion fractures of patella, olecranon, greater tubercle and malleoli (Mullar, 1970). Wolff (1972) used the tension band wire with two small diameter Steinmann pins for the repair of tuber calcanei and proximal ulna in dogs. The two pins gave the better rotational stability to the proximal fragment and the wire provided the compression. Denny (1975) used wire tension band

alongwith Steinmann pins extensively and reported successful treatment of fractures of olecranon, patella, distal and proximal epiphysis of tibia, lateral malleolus of tibia, os calcis and for reposition of fragment in osteotomies of radius in dogs. Phillips (1979) used rush pin in conjunction with tension band wire successfully in the repair of olecranon fracture in two dogs. The wire tension band has been reported to be in use for almost all types of distracted fractures in canines as well as in equines by many other workers also (Lonass, 1982, Byrne 1993). Combined use of cancellous screw and tension wire in treatment of canine olecranon osteotomies has also been reported (Brown, 1978; Palmer, 1988). The main disadvantage of this technique is that it can not be used in comminuted fractures (Denny, 1993). Further, extreme care has to be taken while tightening the wire, as loose wire will not provide adequate fixation and overtight wire may cause a gap in the cranial aspect of the fracture (Bloomberg, 1993).

### ***STAINLESS STEEL PLATING***

The use of steel plates with screws for the fixation of fractures was popularized by Lane in 1910. It is being widely used in Veterinary practice since then. Properly applied steel plate provides the most stable form of fracture fixation (Prieur and Summer-Smith, 1984; De Young and Probst, 1985). Plating is effective in neutralizing all forces that commonly act on fractures i.e. compression, tension, shear, torsion and rotation. The successful use of stainless steel plate in fixation of olecranon fracture has been reported in dogs and horses by many workers (Denny, 1986; Kieran - Bredin, 1987; Bloomberg, 1993). The stainless steel plate applied on caudal aspect of olecranon actually act as a tension band and helped in compressing the fracture line (Denny, 1986). However, proximal fracture of olecranon required plating up to most proximal aspect of the ulna, which resulted in pressure sores, frequently developed over the olecranon, if the plate was applied at caudal aspect. Alternatively, plate can also be applied on the lateral aspect of ulna (Probst, 1990; Bloomberg, 1993). Though, many workers found the plating technique suitable in most of the cases, it can not be applied in all the cases especially if one fragment is too short.

## *LAG SCREW APPLICATION*

Screws alone can also be used to compress the fractured fragments together. Ormrod (1960) described repair of olecranon fracture by wood type screw and transfixation screw Neal (1981) described olecranon fracture repair by use of cancellous or cortical bone screws driven through the proximal portion of olecranon. However, screw can only be used in proximal olecranon fracture and if the fracture involves the articular surface of olecranon 'the semilunar notch', the articular margin of the fracture, serves as a fulcrum and screw will be subjected to excessive bending forces and it may break before fracture healing is complete. Therefore, immobilization of elbow in a plaster cast is recommended (Denny, 1986).

Materials

&

Methods

## MATERIALS AND METHODS

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The study was conducted in 24 clinically healthy, adult mongrel dogs of either sex weighing between 10 to 16 kgs. All the animals were dewormed with albendazole \* @ of 5 mg/kg b.i.d. for 3 days, a month before the start of experiment. They were also vaccinated against 'Rabies' and kept under observation for at least 30 days before the start of experiment. All the animals were maintained under standard feeding and other managerial conditions in kennels of division. Routine clinical and haematological examinations were conducted in all the animals before the start of experiment.

One animal from each group was used for standardization of that particular technique. These animals were not considered for different parameters.

### *SURGICAL PROCEDURE*

The animals were kept off feed and water for 12 hours and 6 hours respectively before surgery. The elbow region was clipped, shaved and prepared for aseptic surgery. The atropine sulphate (@ 0.045 mg/kg subcutaneously) and diazepam\*\* (@ 1 mg/kg intramuscularly) were given fifteen minutes before surgery. General anaesthesia was induced and maintained by 5% solution of thiopental sodium.\*\*\*

The animals were secured in lateral recumbancy. A skin incision starting at the distal third of the humerus and extending up to proximal third of the antebrachium was made on lateral aspect of olecranon as described by Piermattei (1979). The skin was reflected to expose the underlying muscles. Deep antebrachial fascia was incised between the extensor carpi ulnaris and flexor carpi ulnaris. A complete short oblique fracture was then created

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\* Albomar (Agrivet, Farmcare, Bombay)

\*\* Calmpose (Ranbaxy Laboratories, New Delhi)

\*\*\* Intraval Sodium (Rhone - Poulenc India Ltd., Bombay)

just above the anconeal process by using an orthopaedic saw, chisel and hammer. The fracture fragments were reduced with the elbow in extended position. Fracture fragments were then immobilized using a particular technique in different groups as detailed below :-

Group	No. of Animals	INTERNAL FIXATION TECHNIQUE
1	5	Stainless Steel Plating
2	5	Tension band wiring
3	5	Cancellous screw application
4	5	Horn Plating.

Standard stainless steel plates, screws, intramedullary pins and orthopaedic wire were used for the first three groups. Whereas, horn plates were prepared from cadaverous bovine horns as the method adopted by Singh (1986). These plates were sized and shaped up with saw and electrical grinder according to the requirements of test bones ascertained by obtaining their radiograph before surgery.

### *Group - 1*

#### **STAINLESS STEEL PLATING**

In this group a four holed stainless steel plate (approximately 3 c.m. long) and screws (cortical/cancellous) were utilized to fix the fracture. The plate was applied on lateral aspect of olecranon after reducing the fracture. The plate and the bone fragments were held in position and the screws of appropriate size were driven in to screw holes drilled earlier. These screws were tightened alternatively on either side.

### *Group - 2*

#### **TENSION BAND WIRING**

A transverse hole large enough to accommodate a 20 gauge orthopaedic wire was drilled lateromedially distal to the fracture line at a distance roughly equal to the whole length

**Fig. 1-** Photograph showing orthopaedic instruments used in application of different internal fixation devices

(a) Universal bone drill (b) Steinmann pin driver

(c) Orthopaedic wire (d) Stainless steel plate & screws

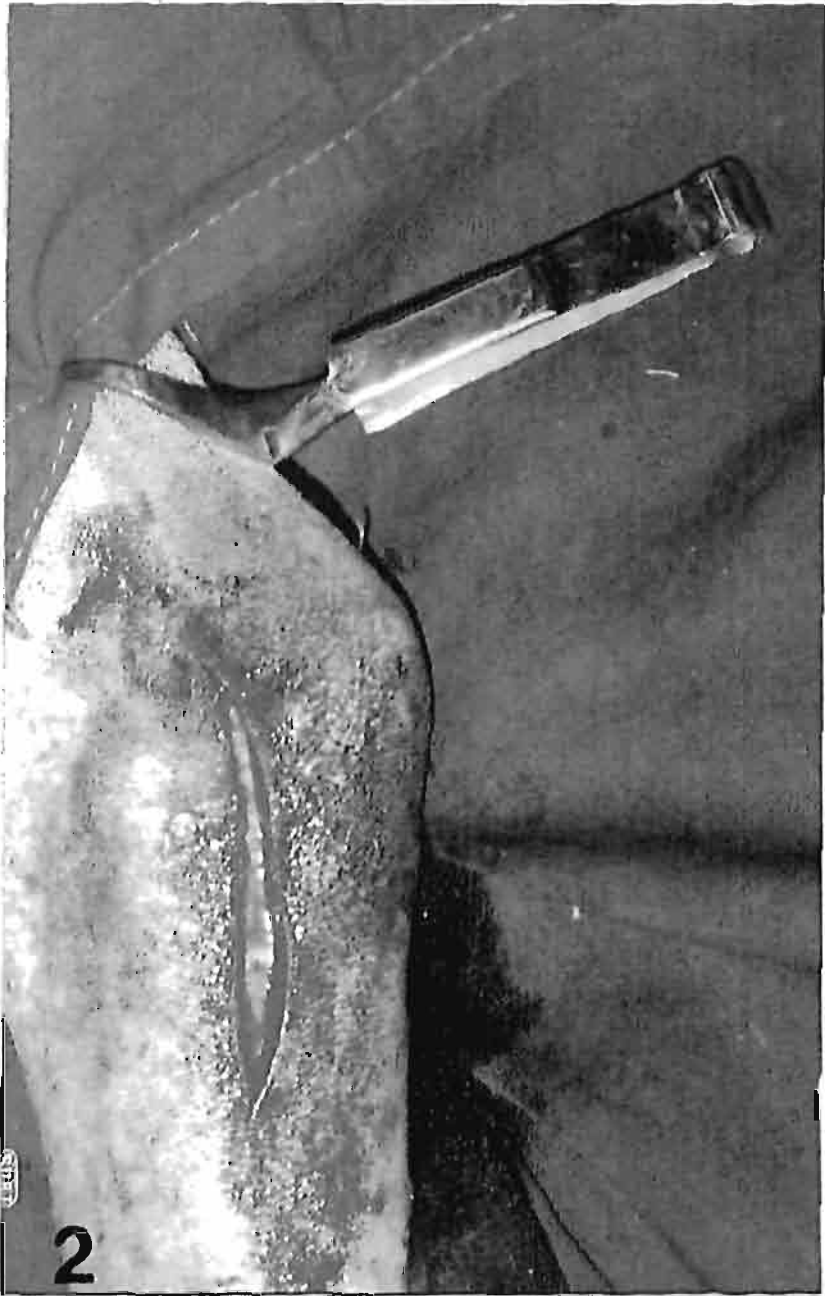
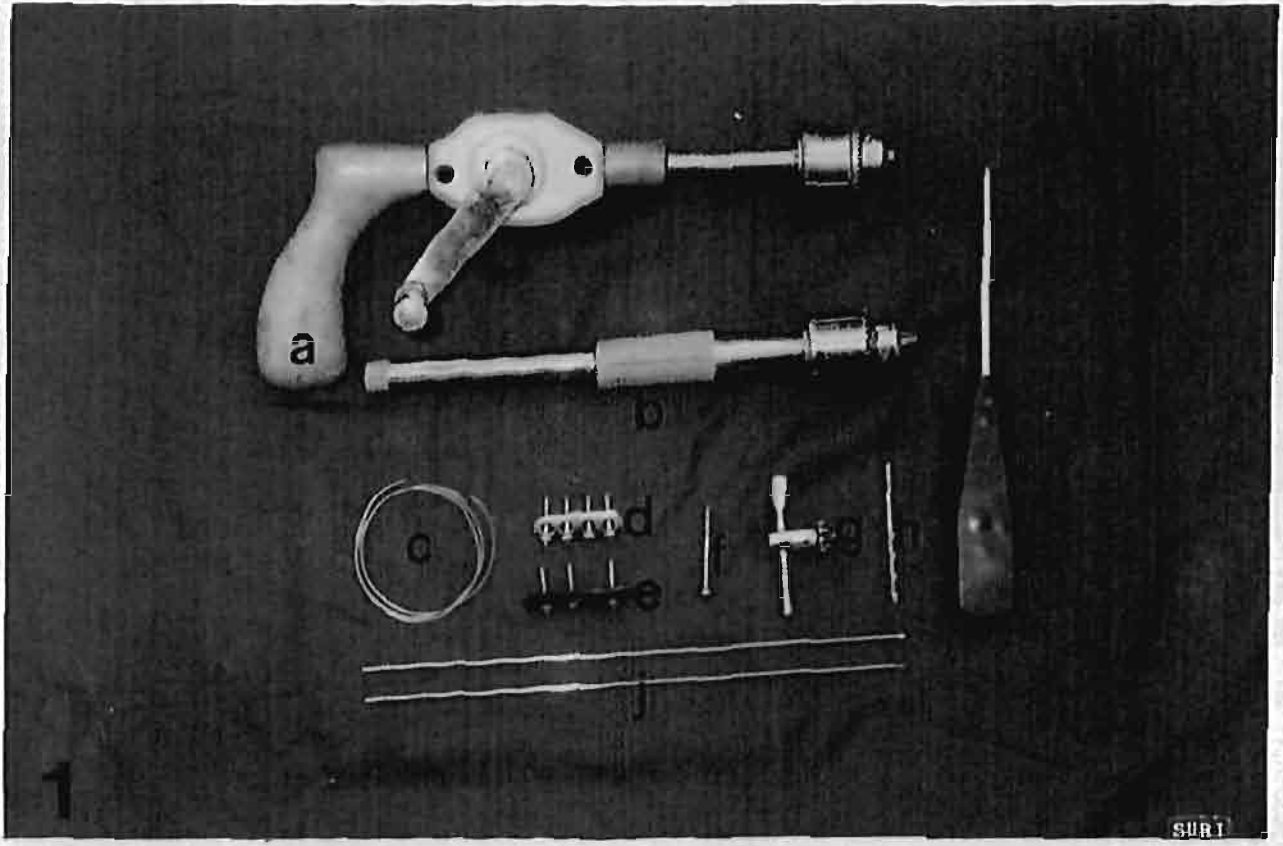
(e) Horn plate & screws (f) Cancellous screw

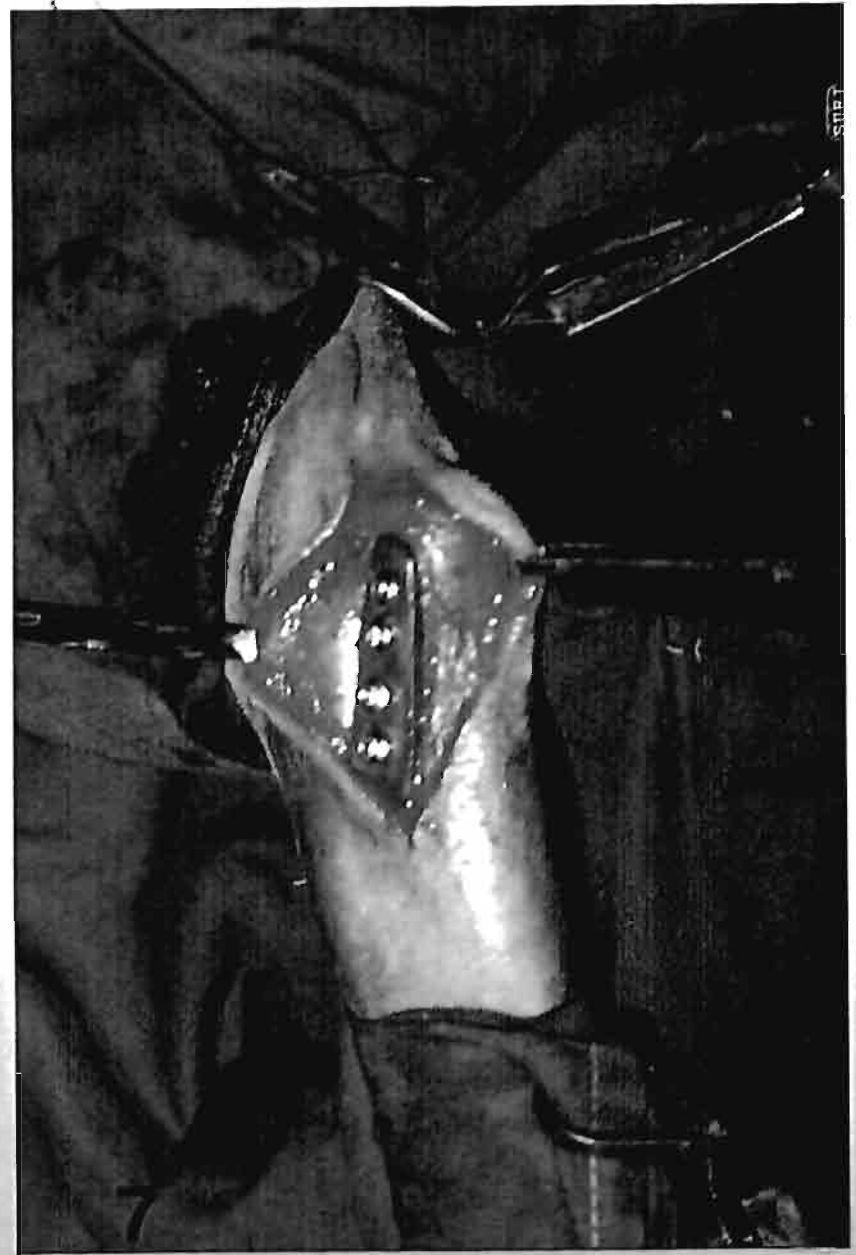
(g) Key of bone drill and Steinmann pin driver

(h) Drill bit (i) Screw driver (j) Small diameter Steinmann pins.

**Fig. 2-** Photograph showing site of incision at elbow

**Fig. 3-** Photograph taken after creation of fracture in olecranon.





of proximal fragment. The orthopaedic wire was inserted in this hole and was left as such to be tightened later on. The fracture fragments were reduced and stabilized by driving two small diameter Steinmann pins across the fracture line.

The pins were driven in a normograde fashion through the proximal extremity of olecranon into the fragments with a Jacob's pin chuck. The care was taken to drive the pins parallel to each other as much as possible to allow proper compression of fracture with the tension band wire. Care was also taken in driving the pins in such a direction that these might engage the cranial cortex of distal ulnar fragment. The pins were bent caudally and cut leaving 2-3 m.m. of cut ends. The ends were then turned cranially so that they might lie flat against the triceps tendon. Another wire was then passed under the cut ends of the pins. The free ends of this wire and the wire placed earlier in distal fragment, were then twisted together after crossing them over the fracture line caudally to form a figure of eight. The two ends were tightened alternatively till the fracture was compressed satisfactorily. The excess wire was then cut off leaving two three twists which were then bent so these might lie flat against the bone to minimize the trauma to the overlying tissues.

### *Group - 3*

#### *CANCELLOUS SCREW APPLICATION*

In this group appropriate sized cancellous screws were used for fracture fixation. Following reduction of fractured fragments, a hole of appropriate diameter and length was drilled from the proximal end of olecranon across the fracture line into the distal ulnar segment. The screw was then fixed into the drilled holes. Care was taken in selection of length of screw so that its threaded portion would remain entirely across the fracture line into the distal segment and hence, can provide proper interfragmentary compression.

### *Group - 4*

#### *HORN PLATING*

Horn Plates of appropriate size (approximately 4 cm x 1 cm x 0.3cm) and stainless steel screws (cortical/cancellous) were used in this group. The horn plates were fixed in the same manner as stainless steel plate in group 1.

Once the fracture fixation was complete, the muscular and subcutaneous sutures were applied routinely using chromic catgut (No. 1-0) in a simple continuous pattern of suturing to cover the fracture site. Skin was sutured using braided silk No. 1 in a simple mattress suturing pattern.

## ***POST OPERATIVE CARE***

All the animals were administered with streptopenicillin\* 0.5 gms b.i.d. for 5 days and phenylebutazone\*\* 2 ml intramuscularly for at least 3 days post operatively. Regular cleaning and dressing of the surgical wound was done with povidone iodine\*\*\* in a routine manner. Skin sutures were removed after 8-10 days or when skin wound was healed. All the animals were given complete rest for first seven postoperative days. After a week light exercise was given to all the animals upto 15 POD's and then they were allowed to walk and run freely for an hour daily.

All the animals were maintained for 60 days post-operatively and different techniques were evaluated and compared on the basis of following observations.

### ***Intraoperative observations***

At the time of surgery the observations like duration of surgery, extent of manipulation and soft tissue damage, degree of technical difficulty, complications if any and the status of fracture reduction and fixation in various groups were recorded. Duration of surgery was recorded as the time required to apply a particular technique after exposure of bone shaft and creation of fixation. The suturing time was also not included.

## ***CLINICAL OBSERVATIONS***

Post operatively all the animals were observed for inflammation, pain, swelling at the fixation site, wound healing, weight bearing and lameness and muscular atrophy of test limb etc., at different intervals.

Inflammation, oedema and muscular atrophy were graded on the scale of zero to

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\*Dicrysticin (Sarabhai Chemicals, Baroda)

\*\* Esgypirin (Sarabhai Chemicals, Baroda)

\*\*\* Betadine (Win-Medicare Pvt. Ltd. New Delhi)

three corresponding to nil, mild, moderate and severe degree respectively. Pain was also graded on the scale of zero to three as follows:

- 0 – No pain on moderate digital pressure at fracture site.
- 1 – Pain on moderate digital pressure at the fracture site.
- 2 – Pain on slight digital pressure at the fixation site.
- 3 – Pain on just touching the fracture site.

Type of wound healing and complications associated with wound healing such as wound dehiscence, exudate formation etc. were also noted.

Weight bearing was recorded by evaluating the animals on a weight bearing score scale of 0-10. Different points were awarded to the animals by observing their performance in three broad locomotary category namely standing, walking and running as given below. Individual score of these three category were added to obtain net weight bearing score of each animal. These observations were tabulated and compared in each group-

### *Standing*

- 0 – Test limb is not touching the ground.
- 1 – Only the toe of test limb is touching the ground.
- 2 – The paw of test limb is touching the ground.

### *Walking*

- 0 – Test limb is not touching the ground.
- 1 – The toe of test limb is touching the ground occasionally.
- 2 – The toe of test is touching the ground frequently.
- 3 – The paw of test limb is touching the ground with partial weight bearing.
- 4 – The paw of test limb is touching the ground with full weight bearing.

## *Running*

- 0 – Test limb is not touching the ground.
- 1 – The toe of test limb is touching the ground occasionally.
- 2 – The toe of test limb is touching the ground frequently.
- 3 – The paw of test limb is touching the ground with partial weight bearing.
- 4 – The paw of test limb is touching the ground with full weight bearing.

Net Score = Score in standing + Score in walking + Score in running.

Rectal temperature, respiration and pulse rate were recorded just before the operation and on day 1, 3, 7, 15 and 30 postoperatively.

## *RADIOLOGICAL OBSERVATIONS:*

(Antero-posterior and mediolateral views of the elbow region were radiographed just after operation and subsequently on 15th, 30th, 45th and 60th postoperative days. The radiographs were observed for status of fracture fixation, fracture healing and complications, if any.

## *HAEMATOLOGICAL AND BIOCHEMICAL STUDY*

Total leukocyte count (T.L.C.), differential leukocyte count (D.L.C.) and serum alkaline phosphatase enzyme estimation were done on day 0, 3, 7, 15 and 30 postoperatively to assess the presence of infection if any and the progress of bone healing.

## *EVALUATION OF FUNCTIONAL STATUS OF ELBOW JOINT*

The degree of extension and flexion of elbow joint was recorded using a goniometer as described by Newton (1985) on different intervals. The values observed on day 15th, 30th, 45th and 60th were compared with the normal value taken on day 0. The full range of motion of elbow joint was also obtained by adding the extension and flexion range and it

was also compared likewise.

Elbow joint angle was also measured while the animal was standing and the values obtained on different intervals in post operative period were compared with normal values taken on day 0.

## **GROSS OBSERVATIONS**

On day 60 the animals of all the groups were euthenized by giving overdoses of thiopental sodium\* intravenously. The test bone was then collected & observed for any reaction in the surrounding soft tissue at the fracture site, status of fixation & implant material, fracture healing, periosteal reaction at the implant & bone interface & presence of infection. The contralateral bone was also collected for comparative evaluation.

## **UNDECALCIFIED GROUND SECTION STUDIES**

Three days before sacrificing the animals, oxytetracycline dihydrate\*\* @ 30 mg/kg was injected intramuscularly to the animals for labeling of new bone. Once the animals were sacrificed at the end of observation period, the test bone was cut longitudinally in two parts so as the fracture site was included in each part. One part was fixed in 10% formaline for histopathological observations, the other part was utilized for undecalcified ground section study. For that 1-2 m.m. sections were cut from this part and kept in water in deep freeze.

The ground undecalcified sections were prepared using the technique of Frost (1958) with slight modification (Parasanalli, 1988). The bone pieces were ground on emery paper of grit numbers 60, 80 and 100 and finally on a hone under moderate pressure using slow circular motions. During fine grinding these sections were repeatedly examined under microscope for desired thickness which was judged on the basis of the presence of structural details of the bone and transparency of the sections.

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\* *Intraval sodium (Rhône-Poulenc India Ltd., Bombay)*

\*\* *Oxystecline (Sarabhai Chemicals, Baroda)*

## ***HISTOPATHOLOGICAL STUDY***

After fixation of bone sections in 10% formaline for one week, these were decalcified in 20% formic acid. Solutions were changed every third day and stirring was also done regularly at least once daily to facilitate decalcification of sections. After proper decalcification these sections were processed routinely for H. & E. staining. The sections were observed for healing at fracture site.

# Results

# RESULTS

The general anaesthesia with 5% thiopental sodium in diazepam premedicated animals was satisfactory to create fracture and its subsequent fixation with different techniques. Curved incision given on lateral aspect of elbow provided good visualization of olecranon with minimum soft tissue trauma. Short oblique fracture was created in olecranon with the help of orthopaedic hand saw, chisel and hammer without any difficulty in all the animals. In five animals (two each in group 1 & 2 and one in group 4) inadvertent involvement of articular surface of ulna was observed during creation of fracture.

## *INTRAOPERATIVE OBSERVATIONS*

Intraoperative observations such as duration of surgery, extent and degree of soft tissue manipulation, degree of technical easiness and status of fracture reduction and fixation have been shown in table 1.

**Table 1: INTRAOPERATIVE OBSERVATIONS**

S.N.	OBSERVATIONS	Group 1	Group 2	Group 3	Group 4
1.	Duration of Surgery (In minutes)	41	56	23	39
2.	Extent of manipulation	++	+++	+	++
3.	Degree of technical easiness	++	+	+++	++
4.	Extent of fracture fixation	+++	+++	+++	+++

Among the different techniques used for fixation of olecranon fracture, the cancellous screw fixation was proved to be the easiest technique, whereas the tension band wiring, the

difficultmost. Consequently the degree of soft tissue manipulation and duration of surgery was also minimum in the animals where cancellous screw fixation was done and maximum where tension band wiring was used.

No major problem was encountered in fixation of olecranon fracture using cancellous screw, stainless steel plate and horn plate except that at few instances, alignment of fracture fragments was slightly disturbed during the process of fixation.

In group 4, only one screw could be placed in the proximal fragment in order to avoid drilling of two holes very close to each other in horn plate in majority of the animals. In tension band wiring, pins could not be placed parallel to each other in any of the animals because of tapering shape of proximal ulna. Therefore, pins were driven in the medullary cavity of distal fragment, till both pins could fit snugly to provide greater stability at fracture site. Besides this, in tension band wiring, the anterior displacement of proximal fragment was frequently observed while rotating bent ends of Steinmann pins cranially to have better anchorage of wire. In this situation the alignment of fragments was corrected either by withdrawing the pins and replacing them in the desired direction or replacing one of the pins with a straight pin.

## ***POST OPERATIVE OBSERVATIONS***

### ***Clinical observations***

The inflammation & weight bearing has been shown in Fig 8 & Fig 9 respectively.

#### ***Group 1***

Mild to moderate degree of inflammation was observed in animals of this group in early postoperative period. The peak inflammatory swelling was observed on day 3 and moderate swelling persisted for 7 postoperative days. Inflammation subsided by day 15 in all the animals. In 2 animals, oedematous swellings, which persisted at this stage, resolved gradually. Postoperative pain also followed the same pattern as of the inflammation and

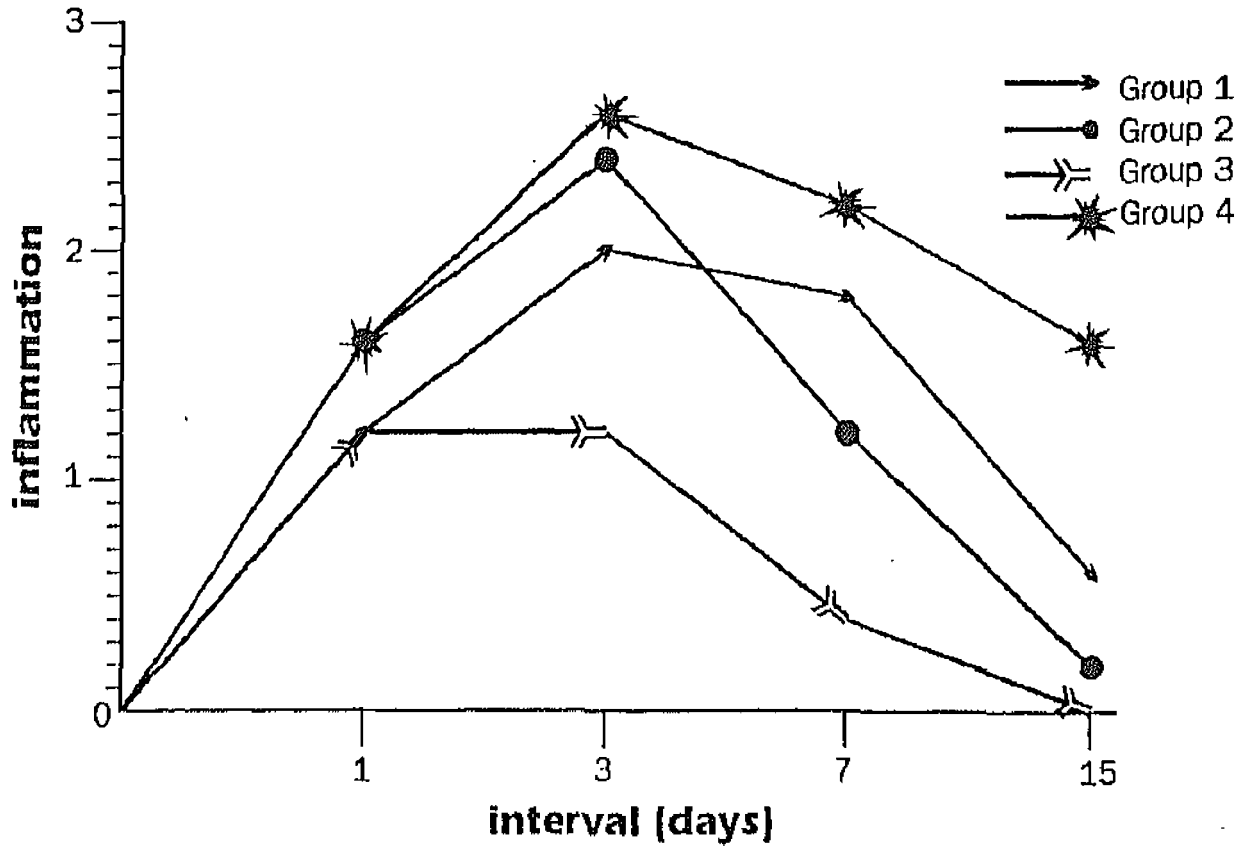


Fig 8 : Mean values of inflammation at different intervals

was severe on 3/4 POD's. Surgical wound healed by first intention in majority of animals, however, in two animals (No. 3 & 16) self inflicted injury resulted in wound dehiscence that took longer time to heal. In another animal (No. 1), purulent discharge oozing from the lower

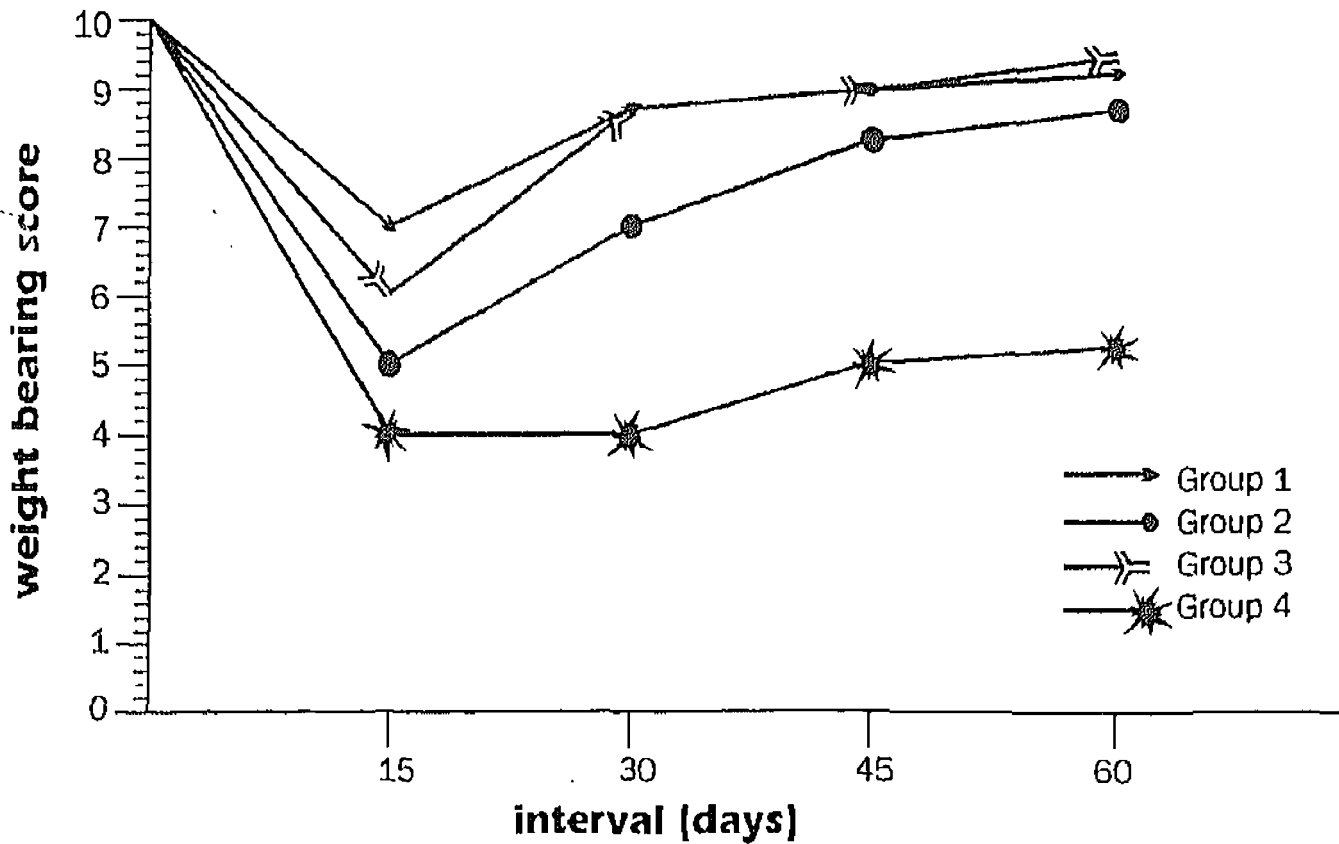


Fig 9 : Mean weight bearing score at different intervals

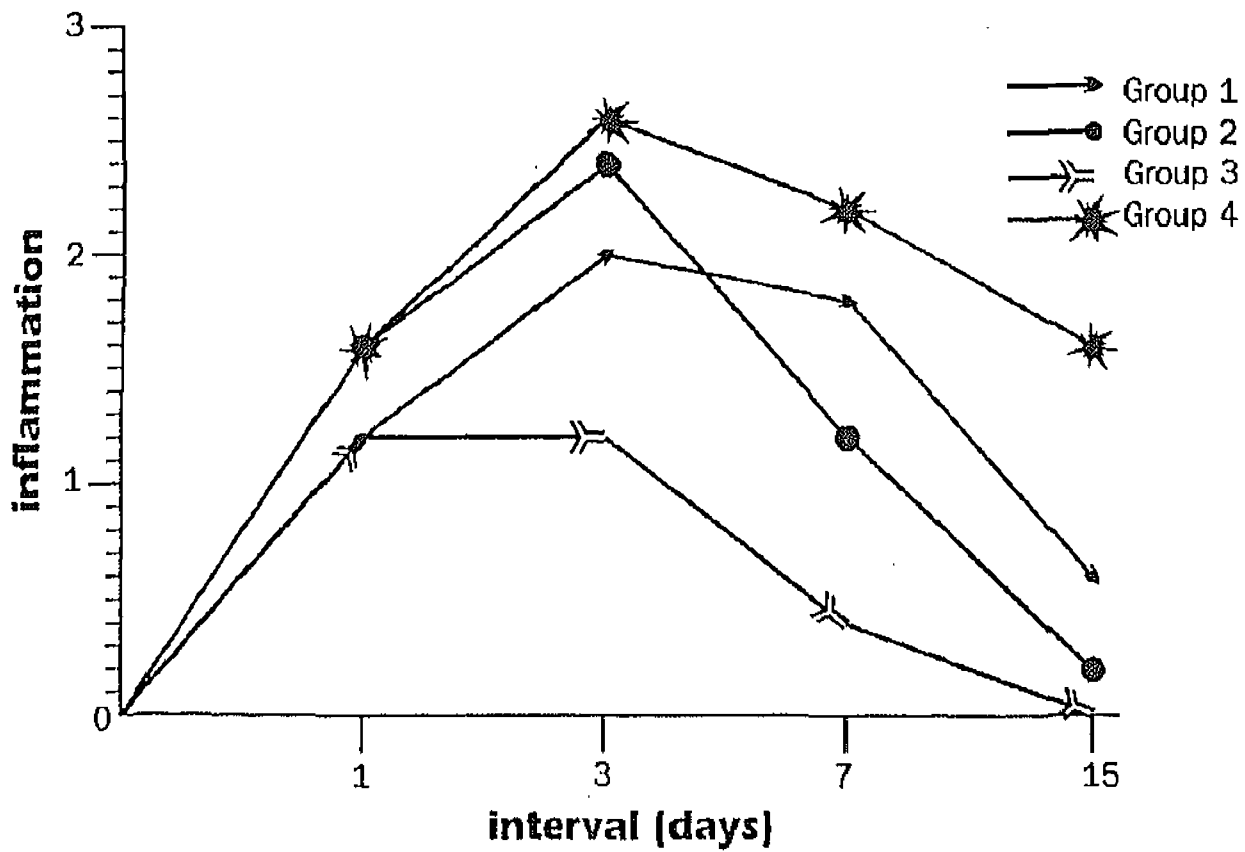


Fig 8 : Mean values of inflammation at different intervals

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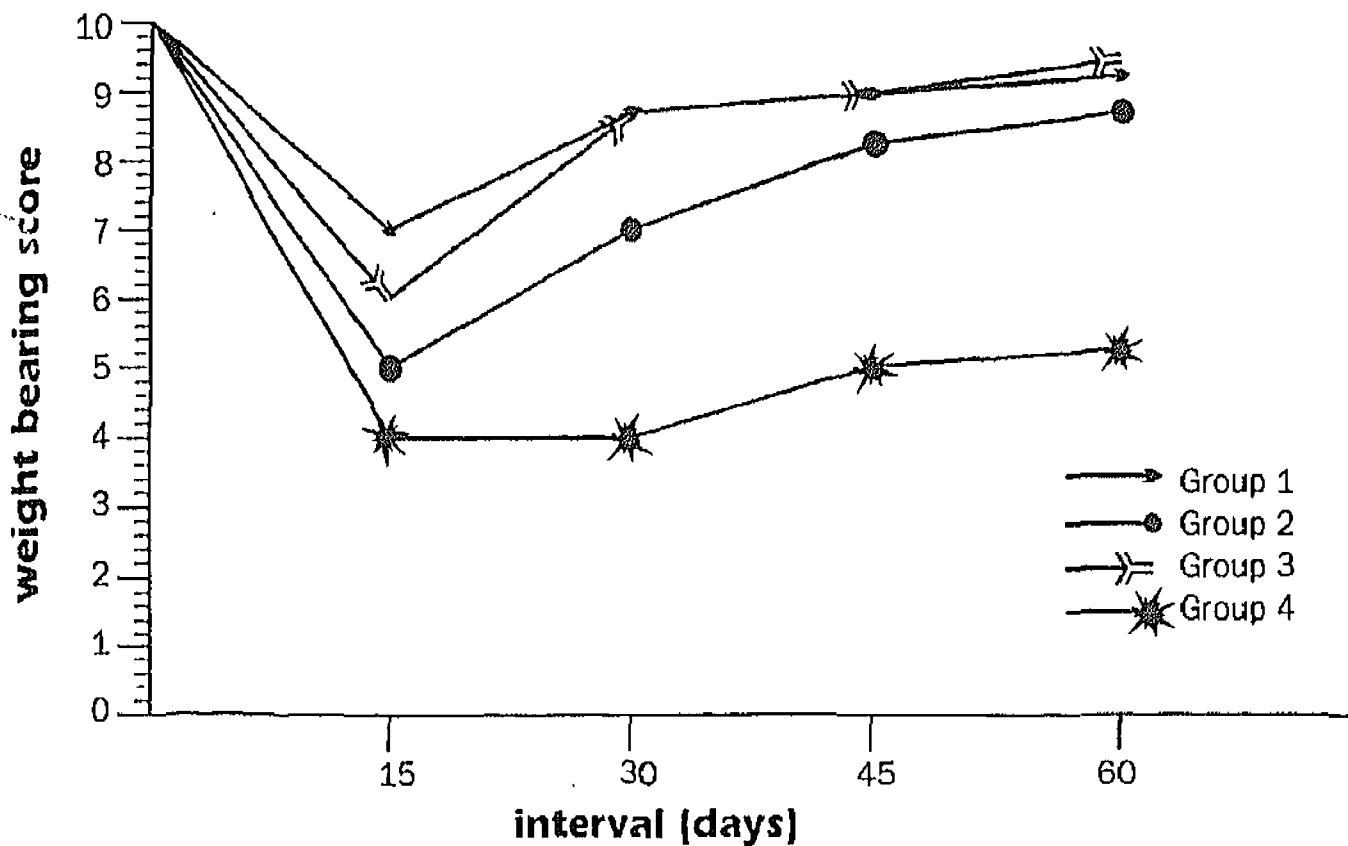
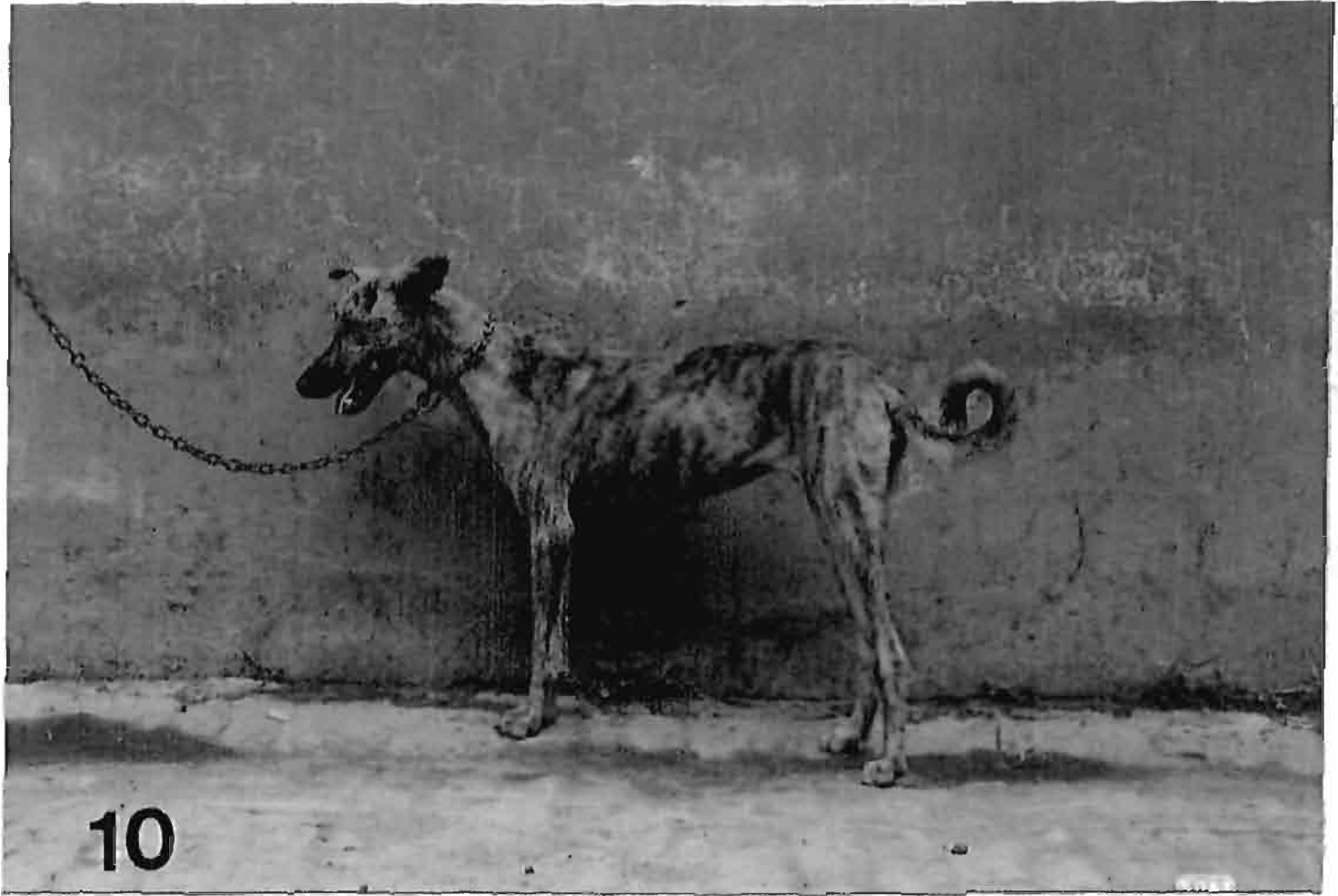


Fig 9 : Mean weight bearing score at different intervals

**Fig. 10-** Animal of group 1 showing full weight bearing on day 30 postoperatively.

**Fig. 11-** Animal of group 2 showing full weight bearing on day 30 postoperatively.



margin of skin wound was noticed on day 15. It persisted upto last day of observation, inspite of regular antiseptic dressing.

All the animals showed full weight bearing immediately after recovery from anaesthesia. Signs of lameness appeared alongwith acute inflammatory phase i.e. from 1-2 days postoperatively. All the animals, however, showed signs of improvement in weight bearing as early as day 7 and progressed steadily till the end of the observation period. Weight bearing in animals of this group was better than animals of group 2 and 4 and was comparable to group 3 in different time intervals. One animal (No. 1) which showed poor weight bearing throughout the observation period, later confirmed to be a case of osteomyelitis. In this animal, moderate muscular atrophy of the test limb was also noticed at later stages. Another animal (No. 16) where fracture line extended the articular surface of ulna showed poor weight bearing in early post operative period but then showed marked improvement from day 15 onwards.

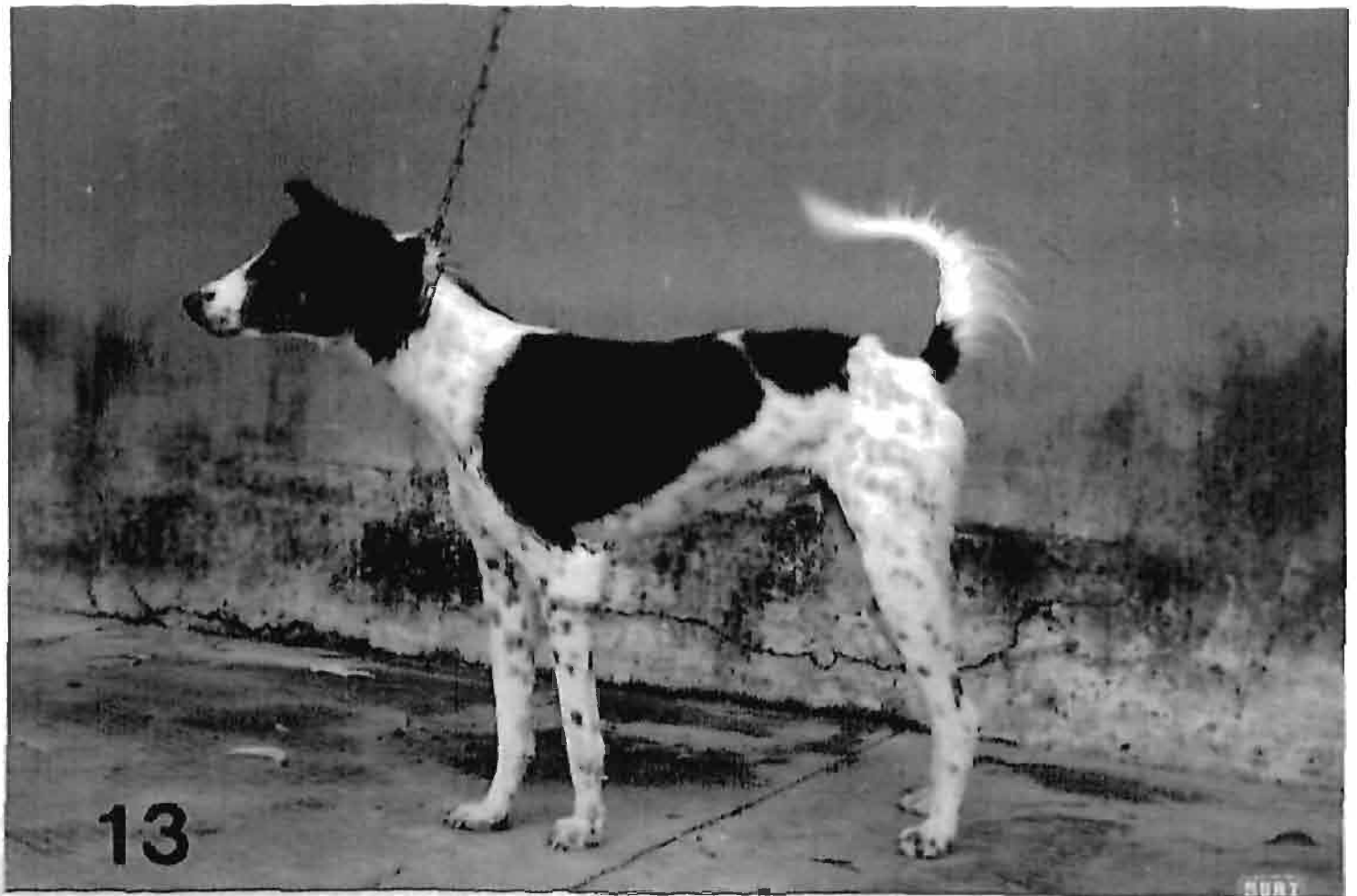
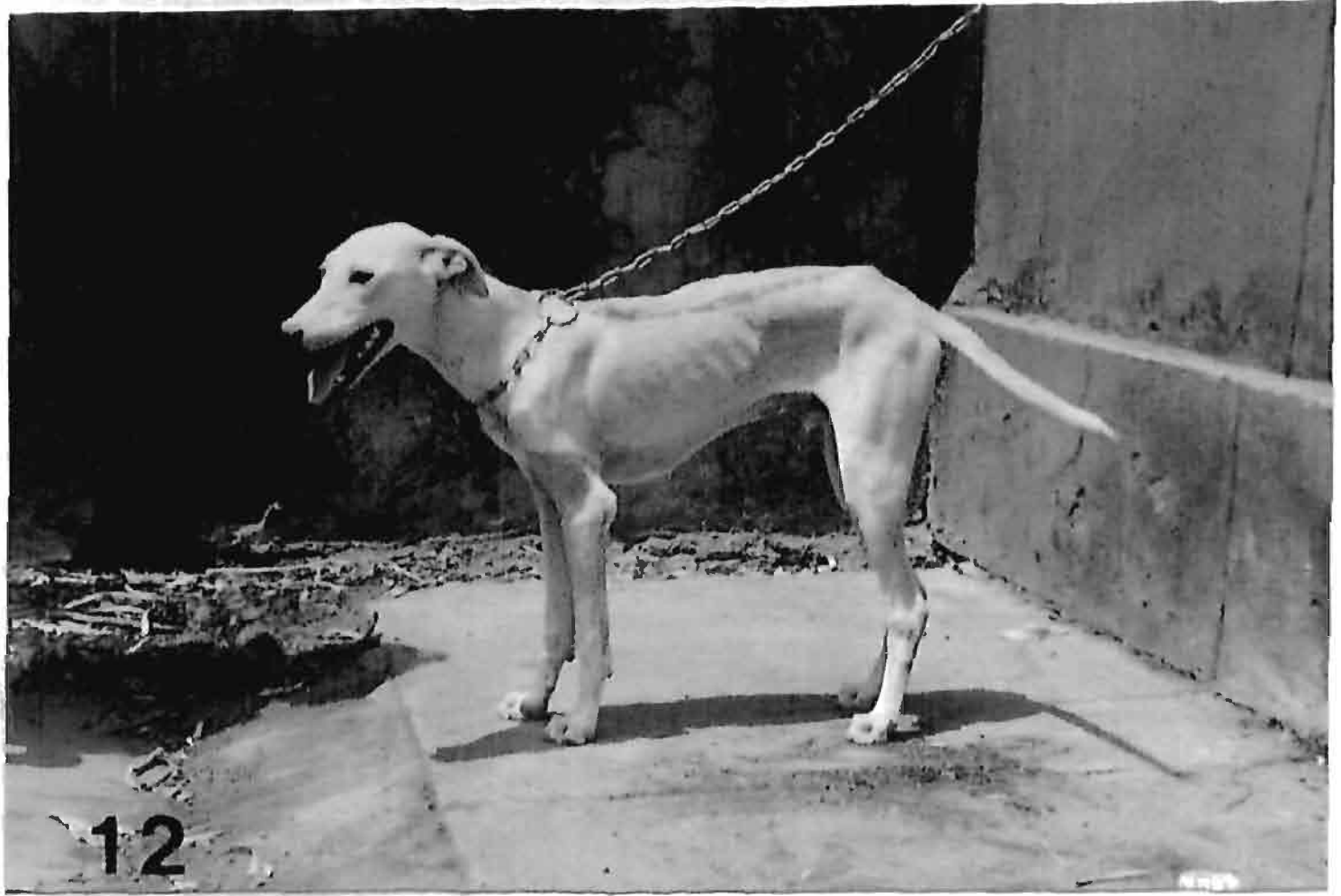
## *Group 2*

Inflammatory swelling was set up earlier in this group and was more pronounced than animals of group 1 and 3. Inflammation and postoperative pain was moderate to severe on day 3. It gradually subsided to reach near normal by 15<sup>th</sup> POD. Mild oedematous swelling was also observed in 2 animals on 7<sup>th</sup> P.O.D. which subsided gradually. Excellent wound healing was seen in animals of this group and surgical wound healed by first intention in all the animals. However, frequent discharge of sero-sanguinus exudate was noticed in one animal (No. 6) from the lower third margin of surgical site (medially) from day 40 till the end of observation period.

In this group also, all the animals showed full weight bearing in immediate postoperative period but evinced pain and exhibited moderate lameness as inflammatory phase started. Animals also showed continuous overall improvement from 15<sup>th</sup> to 60<sup>th</sup> POD's. /

**Fig. 12-** Animal of group 3 showing full weight bearing on day 15 postoperatively.

**Fig. 13-** Animal of group 4 showing full weight bearing on day 45 postoperatively.



One animal (No. 5) where articular surface of ulna was involved during fracture creation, showed no improvement in weight bearing. It continued to carry the test limb throughout the observation period. Whereas the other animal (No. 9) where also the joint was involved, showed gradual improvement in functional weight bearing but the rate of improvement was slower than other animals of this group.

### *Group 3:*

Only mild degree of inflammation was observed in animals of this group in immediate postoperative period and it also subsided faster than in any other group i.e. by 7th P.O.D.) No oedematous swelling was observed in any animals of this group.

Skin wound healed by first intention in all the animals without any complication. Excellent functional weight bearing was observed right from first post operative day. However, weight bearing was affected in subsequent inflammatory period. Animals showed relatively faster improvement in weight bearing from day 15th to 60th.

### *Group 4:*

Animals of this group showed greater degree of inflammation, pain and oedema than any other group. Moderate to severe inflammation was observed in first few postoperative days and moderate inflammation persisted well over 15 days. Similarly, the degree and extent of oedema was also more in all the animals and it persisted for about one month postoperatively. Exudate accumulation and subsequent fistula formation was observed in four animals of this group. Severe wound dehiscence was seen in three animals (No. 17, 19 & 20) of this group. Two animals (No. 19 and No. 20) responded positively to regular antiseptic dressing and the wound healed by second intention by day 30. However, slight accumulation of purulent exudate and subsequent fistulous tract formation in the lower margin of wound was observed around day 40 in these animals, which continued throughout the observation period. In another animal (No. 17) no improvement was seen and the horn plate was completely exposed. This plate had to be removed and then the wound healed by second intention by day 50.

Good weight bearing was observed in all the animals of this group in the immediate postoperative period, but animals started carrying the limb and showed greater degree of lameness as inflammation progressed. However, good improvement in weight bearing was observed in two animals (No 18 & 20) after day 30. Whereas remaining three animals (No 17, 19 & 22) did not show any appreciable improvement till the end of observation period.

Rectal temperature, respiration and pulse rates showed transient increase in early postoperative period from day 1 to 7 in all the animals irrespective of groups. These values gradually returned to normal by day 15. No significant difference was seen when the values were compared between different groups (table 2, 3 & 4).

**Table 2 Mean ( $\pm$  S.E.) Heart rate (Per mln) at different Intervals**

Group	Intervals (Days)					
	0	1	3	7	15	30
1	84.50 $\pm$ 1.78	96.50* $\pm$ 0.43	98.50 $\pm$ 2.94	96.00 $\pm$ 1.58	90.50 $\pm$ 2.94	89.25 $\pm$ 2.21
2	86.50 $\pm$ 5.35	94.75 $\pm$ 5.30	97.00 $\pm$ 3.84	89.00 $\pm$ 5.67	84.50 $\pm$ 4.26	86.00 $\pm$ 4.35
3	84.00 $\pm$ 1.22	98.00 $\pm$ 3.93	100.50 $\pm$ 3.26	87.50 $\pm$ 1.47	85.00 $\pm$ 1.11	84.50 $\pm$ 0.43
4	78.50 $\pm$ 2.16	88.00 $\pm$ 1.22	92.00 $\pm$ 2.12	90.00 $\pm$ 2.73	84.50 $\pm$ 3.89	82.50 $\pm$ 2.38

\*Significantly different from the base value ( $P < 0.05$ )

**Table 3 Mean ( $\pm$  S.E.) respiration rate (Per min) at different intervals**

Group	Intervals (Days)					
	0	1	3	7	15	30
1	23.75 $\pm$ 0.89	26.50 $\pm$ 0.43	26.50 $\pm$ 0.82	26.75 $\pm$ 0.96	25.25 $\pm$ 1.08	25.00 $\pm$ 0.86
2	24.50 $\pm$ 0.82	27.50 $\pm$ 1.29	28.25 $\pm$ 1.67	26.25 $\pm$ 1.67	24.25 $\pm$ 1.13	24.25 $\pm$ 1.43
3	25.00 $\pm$ 1.11	28.50 $\pm$ 1.08	28.50 $\pm$ 1.47	26.50 $\pm$ 0.82	25.00 $\pm$ 0.50	23.50 $\pm$ 0.43
4	22.00 $\pm$ 0.70	26.00 $\pm$ 0.70	26.00 $\pm$ 0.89	24.00 $\pm$ 0.00	23.75 $\pm$ 0.73	23.25 $\pm$ 0.64

**Table 4 : Mean ( $\pm$  S.E.) rectal temperature ( $F^{\circ}$ ) at different intervals**

Group	Intervals (Days)					
	0	1	3	7	15	30
1	101.37 $\pm$ 0.20	102.50 $\pm$ 0.17	102.25 $\pm$ 0.27	101.75 $\pm$ 0.27	101.25 $\pm$ 0.12	101.37 $\pm$ 0.10
2	101.62 $\pm$ 0.32	103.00* $\pm$ 0.30	103.37* $\pm$ 0.40	102.00 $\pm$ 0.17	101.25 $\pm$ 0.21	101.62 $\pm$ 0.27
3	101.37 $\pm$ 0.20	102.62 $\pm$ 0.27	102.62 $\pm$ 0.20	101.37 $\pm$ 0.20	101.37 $\pm$ 0.20	101.37 $\pm$ 0.20
4	101.50 $\pm$ 0.30	103.12 $\pm$ 0.27	103.37 $\pm$ 0.20	102.75 $\pm$ 0.37	101.50 $\pm$ 0.25	101.62 $\pm$ 0.32

\*Significantly different from the base value ( $P < 0.05$ )

## ***RADIOLOGICAL OBSERVATIONS***

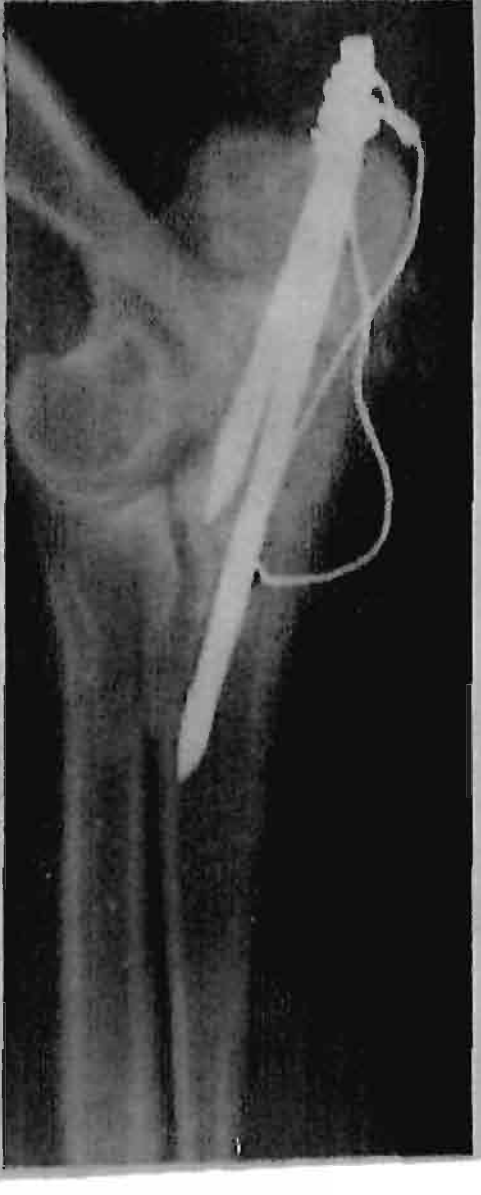
### ***Group 1 :***

The view of fracture site was nearly completely blocked by the radio-opaque stainless steel plate in majority of animals in the lateral radiographs taken soon after fracture fixation. Antero-posterior view also could not facilitate much to visualize fracture line due to the superimposition of elbow joint over olecranon. Hence, it was difficult to make correct assessment of fracture healing in early stages. However, a part of fracture line and changes related to healing around this could be seen well in two animals (No. 8 & 16). The periosteal callus and new bone formation exceeding the margin of stainless steel plate could be seen easily in later stages in all the animals.

Radiographs taken immediately after fracture fixation showed excellent alignment of fractured fragments in all the animals. In the animals where fracture site was visible, excellent reduction could be seen radiographically. Alignment was maintained in all the animals in subsequent intervals also. The screws and plates remained fixed at their respective positions throughout the observation period. Four out of five animals showed normal course of fracture healing. One animal (No. 16) among these four showed signs of periosteal callus formation in the radiograph taken on 15th POD, though the amount of callus was very little. The remaining three animals did not show periosteal callus, formation at this interval. However, by day 30 periosteal callus became visible in rest of the animals also. *Further increase in amount and density of the callus was observed on day 45. Cortical thickening distal to the lower margin of plate was observed in two animals (No. 4 & 16) on day 30 and it increased in density on day 45. On day 60, the reduced amount and more organisation of callus indicated initiation of remodeling process. The periosteal thickening which was observed in two animals at 30th POD, also reduced considerably by day 60. Complete obliteration of fracture line was also observed in both the animals where the view of fracture line was not blocked by stainless steel plate completely. (No. 8, 16).*

**Fig 14-16** Lateral radiographs of animal of group 1 showing normal course of fracture healing (Fig 14-day 0; Fig 15-day 30; Fig 16-day 60).

**Fig 17-19** Lateral radiographs of animal of group 2 showing normal course of fracture healing (Fig 14-day 0; Fig 15-day 30; Fig 16-day 60).



One animal (No. 1) of this group showed extensive periosteal reaction as early as 15th POD which was extending upto approximately 4 c.m. distal to the lower margin of plate. This animal showed signs of osteomyelitis subsequently. A distinct sequestrum near fracture site was noticed on day 30 and periosteal callus formation was also extensive. Though fracture line was obliterated by osseous tissue by day 60, exuberance of new bone was much and the medullary canal appeared as dense as the cortex in 1 cm. area distal to the lower margin of plate.

## *Group 2*

Radiographs taken soon after the fracture fixation provided the complete details about the position of pins and wires and status of reduction and alignment of fractured fragments. These showed that one pin was invariably shorter than the other in all the animals of this group, however, reduction and alignment was satisfactory in all animals. Subsequently, this alignment and reduction was maintained, in four animals. The pins and wire also remained fixed at their respective positions in three out of these four animals throughout the observation period.

Four animals showed normal course of healing and uneventful recovery. In these animals very little periosteal callus formation was evident on day 15 but it increased in amount and density in the radiographs taken at subsequent intervals. In one animal (No. 10), the periosteal callus was not visible even on day 30. By day 45, the callus completely obliterated the fracture line in two animals (No. 3 & 9) and the fracture line was not visible. In remaining two animals (No. 6 & 10) though radiodensity at fracture gap was increased but fracture line remained visible even upto day 60. The amount of callus, however, decreased and indicated start of remodeling process.

In one animal (No. 5) in which fracture line extended upto articular surface of ulna during creation of fracture, anterior displacement of proximal fragment with fracture gap of about 1.5 mm was seen in the radiographs taken on first postoperative day, slight bending

of one pin was observed in this case. However, this gap did not increase further and the animal showed healing process in the subsequent radiographs. The fracture gap was nearly filled completely by new bone by day 60.

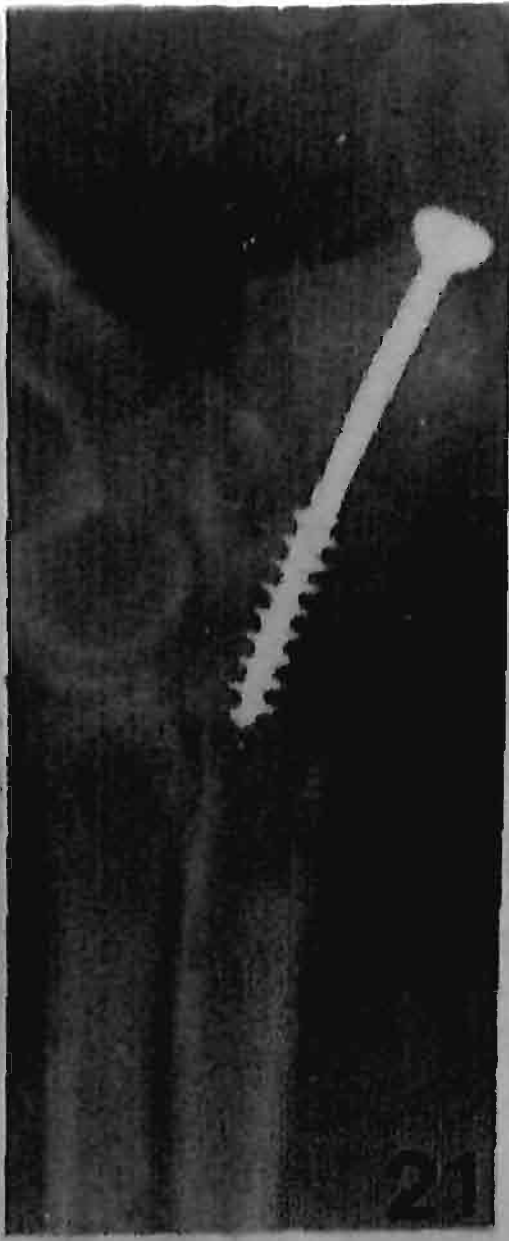
Breakage of wire near its inserion site into the hole in distal fragment was seen in *one animal (No. 9) on day 45. However, no change in the position of pins was noticed and the animal showed normal fracture healing as described earlier. In animal No. 10 stretching of wire was seen on day 15 and the fracture gap increased slightly but pins remained fixed subsequently and normal fracture healing was seen.*

### *Group 3*

Radiographs taken immediately after fracture fixation revealed proper placement of screw with good reduction and alignment of fractured fragments in majority of animals. The screw remained in its position as such in all the animals and therefore reduction and alignment of fractured fragments was maintained satisfactory throughout the observation period. All the animals of this group showed normal course of fracture healing. On the 15th POD all the animals showed signs of periostial callus formation as evidenced by increased radiodensity near the fracture line. On day 30, callus activity was appreciably pronounced and periosteal new bone formation was seen. Fracture line was clearly visible in all the animals at this interval. A distinct increased radiodensity around screw head was observed in one animal (No. 11). On day 45, the callus obliterated the fracture gap completely in one animal (No. 11) but the remaining animals showed only advanced stage of fracture healing, evidenced by further increase in radiodensity in fracture gap and in the surrounding callus. However, fracture line remained faintly visible at this interval. On day 60, radiographs revealed obliteration of fracture gap in rest of the animals also and the fracture line was not visible. Normal trabecular pattern of bone was restored and cortical continuity was also established in three animals. Callus size was reduced showing the signs of remodeling.

**Fig. 20-22** Lateral radiographs of animal of group 3 showing normal course of fracture healing (Fig 14-day 0; Fig 15-day 30; Fig 16-day 60).

**Fig. 23-25** Lateral radiographs of animal of group 4 showing normal course of fracture healing (Fig 14-day 0; Fig 15-day 30; Fig 16-day 60).



**Fig. 26-27** Lateral radiographs of an animal of group 2 showing proper fixation at day 0 (Fig 26) and breakage of tension wire at day 45 (Fig 27).

**Fig 28-29** Lateral radiographs of an animal of group 4 showing proper fracture fixation at day 0 (fig 28) and anterior displacement of proximal fragment at day 15 (fig 29).



## *Group 4*

Being radiolucient in nature, the horn plate did not block the view of fracture line in the radiographs. Therefore, better assessment of fracture healing at fracture site could become possible in this group, when compared to group 1.

The radiographs taken soon after surgery revealed satisfactory fixation of fracture. The reduction and alignment of fractured fragments was good in majority of animals. This was maintained in three animals (No. 18, 20 & 22) during subsequent period and screws and plates remained fixed at their position in these animals throughout the observation period. Among these three animals two animals (No. 18 & 20) showed normal course of healing. In these two animals little periosteal activity was seen on 15th P.O.D. The periosteal new bone formation was more pronounced on day 30 and the callus was seen bridging the fracture gap. The periosteal proliferation was more when compared to other groups at this interval. The callus completely obliterated the fracture gap by day 45 and the fracture line was not visible in one animal (No. 20). The organisation and remodeling of periosteal new bone was observed at this interval but the new bone exuberance along the posterior aspect of olecranon, particularly distal to fracture line appeared more radiodense. At day 60 the normal trabecular pattern of bone was restored in other animal (No. 18) also and the advanced stage of callus remodeling was seen.

In two animals (No. 17 & 18) of this group, distraction of proximal fragment was observed on day 15. In these animals the breakage of bone near the fracture line in the proximal fragment in one animal (No. 17) and the deviation in the direction of screw from its original placement in the other (No. 19) was observed. These animals showed extensive new bone formation in early postoperative period. This new bone reduced in size in one animal (No. 17) after removal of horn plate but continued in another one (No. 19) where horn plate was not removed. However, no union at fracture site was observed in both the animals till the end of observation period. Osteomyelitis was also observed in one animal (No. 22) on day 30 and excessive new bone proliferation giving it a mottled appearance was noticed on day 45. However, no callus bridging the gap was noticed.

## Haematological and biochemical studies

Mean ( $\pm$  S.E.) total leukocyte count (T.L.C.) of all the groups at different observation intervals have been shown in table 9.

**Table 9 : Mean ( $\pm$  S.E.) total leukocyte count (thousand/Cubic ml) at different intervals**

Group	Intervals (Days)				
	0	3	7	15	30
1	13.22 $\pm$ 0.54	16.22* $\pm$ 0.96	18.26* $\pm$ 0.78	13.50 $\pm$ 0.34	12.96 $\pm$ 0.61
2	10.83 $\pm$ 0.45	18.93* $\pm$ 0.61	19.62* $\pm$ 0.78	13.89 $\pm$ 0.54	10.96 $\pm$ 0.54
3	10.53 $\pm$ 1.28	15.13* $\pm$ 1.09	16.28* $\pm$ 0.85	10.66 $\pm$ 0.74	11.36 $\pm$ 0.86
4	12.40 $\pm$ 0.56	14.98* $\pm$ 0.26	22.08* $\pm$ 1.06	19.39* $\pm$ 1.54	13.92 $\pm$ 1.29

\*Significantly different from the base value ( $P < 0.05$ )

A significant increase ( $P < 0.05$ ) in T.L.C. was observed in all the animals of different groups on third postoperative day. It further increased upto day 7 postoperatively and then showed a downward trend to reach near normal at 15th POD in group 1 and 3 and at 30th POD in group 2 and 4. When compared between different groups, no significant difference was seen at any interval.

DLC also did not show any appreciable variation among the different groups. A relative increase in neutrophils and decrease in lymphocytes was observed up to day 7

postoperatively which came to near normal gradually at subsequent intervals. There was no significant variation in the DLC among the animals which developed infection when compared to those which recovered without any complication.

Serum alkaline phosphatase (Mean  $\pm$  S.E.) values (KA units) recorded in animals of different groups have been shown in table 10. The enzyme activity increased significantly on day 7th postoperatively and showed a continuous increasing trend up to day 30. However, the rate of increase after day 15 was less. No significant difference in the enzyme activity was recorded among different groups at any interval.

**Table 10 : Mean ( $\pm$  S.E.) serum alkaline phosphatase (KA units) at different Intervals**

Group	Intervals (Days)				
	0	3	7	15	30
1	7.86 $\pm$ 1.46	8.05 $\pm$ 1.12	11.46 $\pm$ 2.02	16.28* $\pm$ 2.16	17.12* $\pm$ 1.92
2	6.54 $\pm$ 1.31	8.92 $\pm$ 1.80	13.26* $\pm$ 1.50	15.16* $\pm$ 2.06	15.96* $\pm$ 2.14
3	6.73 $\pm$ 2.46	8.31 $\pm$ 1.36	12.30* $\pm$ 1.05	17.16* $\pm$ 2.06	18.91* $\pm$ 1.86
4	8.46 $\pm$ 1.34	11.28 $\pm$ 2.36	11.96* $\pm$ 1.50	18.12* $\pm$ 2.06	17.98* $\pm$ 2.62

\*Significantly different from the base value (P<0.05)

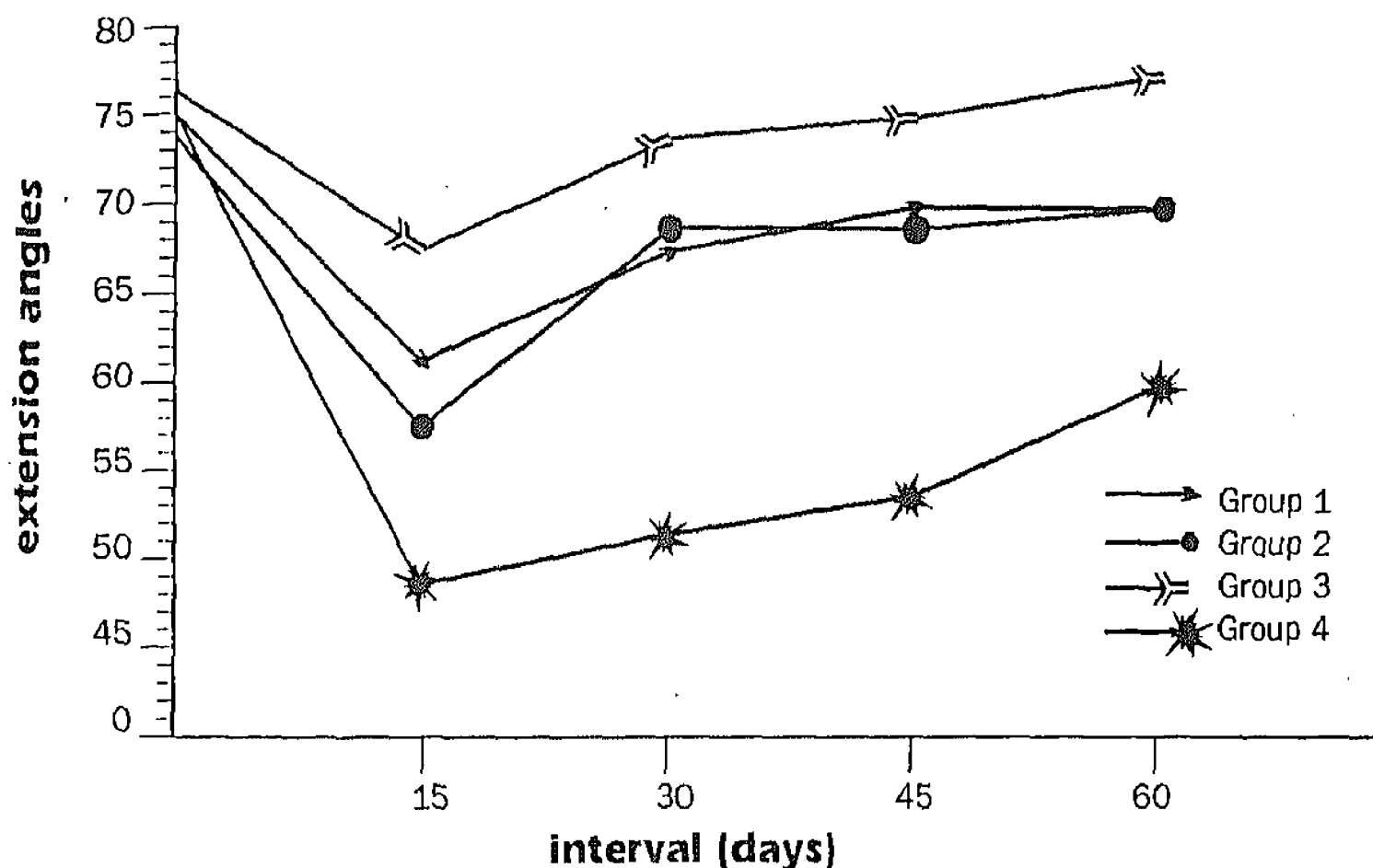
### *Evaluation of functional status of elbow joint*

Extension, flexion and normal standing angles of elbow joint of all the animals of different groups were determined by as described by Newton (1985). Only four animals from

each group were included for statistical analysis because of development of osteomyelitis in one animal each in group 1 and 4.

### *Extension angle*

Extension angles (Mean  $\pm$  S.E.) recorded at different intervals in all the four groups have been shown in fig. 30 and table 5. In all the groups, significant ( $P < 0.05$ ) decrease in



*Fig 30 : Extension angles of elbow joint (Mean) at different intervals*

the extension angle was observed on day 15. This reduction was highest in group 4 and lowest in group 3, whereas group 1 and 2 were comparable to each other. Thereafter a marked improvement in these values was seen in groups 1, 2 and 3. The values reached near normal on day 30, 45 and 60 in group 3, group 1 and group 2 respectively. The animals of group 4 showed slower improvement in the values of extension angle and these values remained significantly lower than base values till day 45. However, appreciable increase in

**Table 5: Extension angles of elbow joint (Mean± S.E.) In dogs of different group.**

Group	INTERVALS (DAYS)				
	0	15	30	45	60
1	75.00 ± 0.00	61.25* ± 2.07	67.50 ± 3.75	70.00 ± 3.06	70.00 ± 3.06
2	73.75 ± 1.08	57.50* ± 3.75	68.75 ± 3.24	68.75 ± 3.24	70.00 ± 3.06
3	76.25 ± 1.08	67.50* ± 1.25	73.75 ± 2.07	75.00 ± 2.50	77.5 ± 1.25
4	75.00 ± 0.00	48.75* ± 2.07	51.25* ± 3.24	53.75* ± 4.46	60.00 ± 5.59

\*Significantly different from the base value (P<0.05)

extension angle was seen by 60th postoperative day but the values were still below the base values.

### *Flexion angle :*

Flexion angles (Mean ± S.E.) recorded at different intervals in all the four groups have been shown in Fig. 31 and table 6. Marked decrease in flexion angle was noticed on day 15 in all the groups of animals. This reduction in flexion angle was significant (P<0.05) in group 2 only but thereafter continuous improvement was observed and the values reached near normal by day 45 in this group. The animals of group 1 showed gradual improvement approaching towards normal base value by day 60. In group 3, the elbow flexion angles did not show any marked change at different recording intervals and remained near normal throughout the period of study. However, in group 4, decreasing trend in the values of elbow

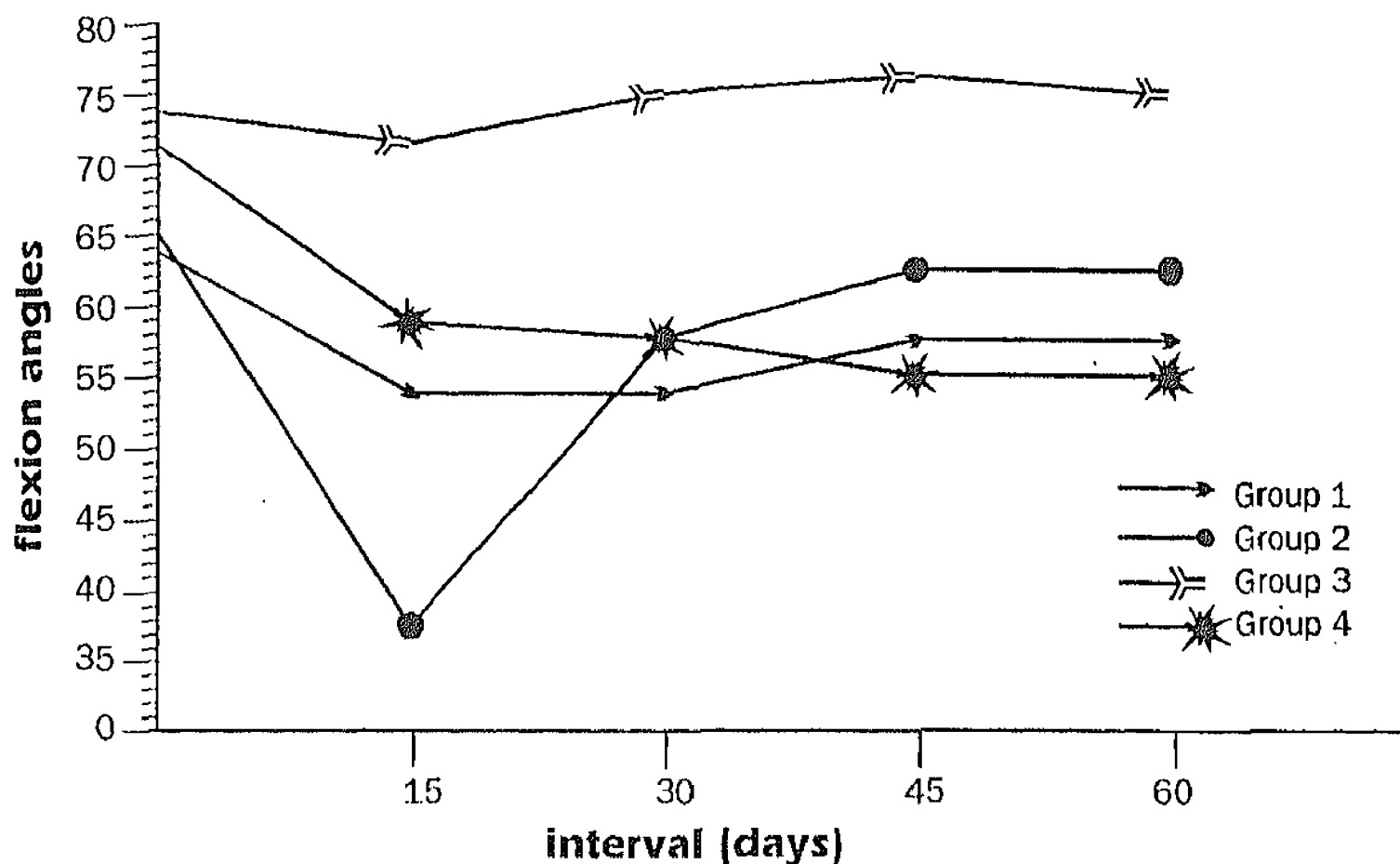


Fig 31 : Flexion angles of elbow joint (Mean) at different intervals

Table 6: Flexion angle of elbow joint (Mean  $\pm$  S.E.) in dogs of different groups.

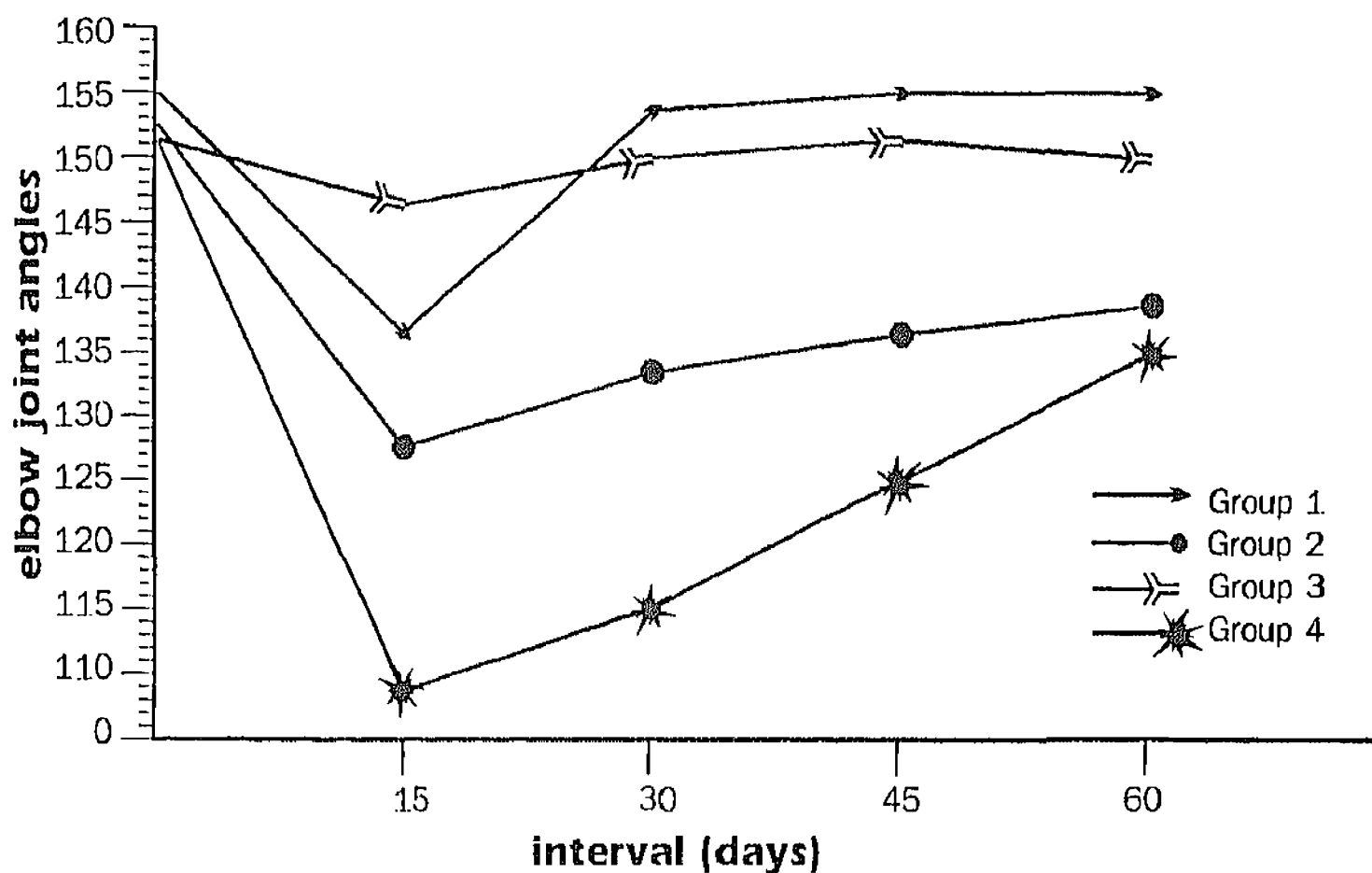
Group	INTERVALS (DAYS)				
	0	15	30	45	60
1	63.75 $\pm$ 2.07	53.75 $\pm$ 3.24	53.75 $\pm$ 2.72	57.50 $\pm$ 3.75	57.50 $\pm$ 2.71
2	65.00 $\pm$ 1.76	37.5* $\pm$ 8.92	57.50 $\pm$ 2.79	62.5 $\pm$ 4.50	62.50 $\pm$ 3.75
3	73.75 $\pm$ 2.07	71.25 $\pm$ 1.08	75.00 $\pm$ 0.00	76.25 $\pm$ 1.08	75.00 $\pm$ 0.00
4	71.25 $\pm$ 2.07	58.75 $\pm$ 4.80	57.50 $\pm$ 4.14	55.00 $\pm$ 3.53	55.00 $\pm$ 3.06

\*Significantly different from the base value (P<0.05)

flexion angles was observed and values remained considerably lower than the base value till day 60.

### *Angle of elbow joint in standing position*

Mean ( $\pm$  S.E.) standing angles of elbow joint recorded at different intervals in animals of different groups have been shown in Fig. 32 and table 7.



*Fig 32 : The elbow joint angles (Mean) when the animal is standing normally, at different intervals*

Mean of normal standing angle of elbow joint of the test limb ranged from 152.50 ( $\pm$  2.16) to 155 ( $\pm$  0.00) in different groups of animals at day 0. Significant decrease ( $P < 0.05$ ) in values of standing angles was observed on day 15 in groups 1, 2 and 4. This reduction in the values was highest in group 4 and lowest in animals 1. Values of standing angles remained significantly low up to day 45 in group 2 and 4, whereas improved to reach near normal by day 30th post operatively in group 1. Though animals of group 2 and 4

**Table 7 : The elbow joint angle (Mean  $\pm$  S.E.) when the animal is standing normally.**

Group	INTERVALS (DAYS)				
	0	15	30	45	60
1	155.00 $\pm$ 0.00	136.25* $\pm$ 5.41	153.75 $\pm$ 1.08	155.00 $\pm$ 0.00	155.00 $\pm$ 0.00
2	152.50 $\pm$ 1.25	127.50* $\pm$ 6.41	133.75* $\pm$ 6.46	136.25* $\pm$ 6.21	138.75 $\pm$ 5.69
3	152.50 $\pm$ 2.16	146.25 $\pm$ 3.24	150.00 $\pm$ 2.50	151.25 $\pm$ 2.07	150.00 $\pm$ 1.76
4	152.50 $\pm$ 1.25	103.75* $\pm$ 8.36	115.00* $\pm$ 9.01	125.00* $\pm$ 11.59	135.00 $\pm$ 6.84

\*Significantly different from the base value ( $P < 0.05$ )

showed continuous improvement in these values but the angles remained markedly low on day 60 in both the groups. In group 3, these angles were near normal right from day 15 to day 60.

### *Range of motion*

Range of motion of elbow joint (Mean  $\pm$  S.E.) recorded at different intervals was shown in fig. 33 and table 8.

Mean of normal range of motion of elbow joint ranged from 138.75 ( $\pm$  2.70) in group 1 to 150.00 ( $\pm$  1.76) in group 3. Range of motion of elbow joint decreased significantly ( $P < 0.05$ ) on day 15 in animals of all the groups. This reduction was highest in group 2, medium in group 1 and 4 and lowest in group 3. These values showed gradual improvement in all the groups and values reached near normal range by day 30 in group 3. Considerable improvement in range of motion was also recorded in animals of group 1 and 2 on day 45

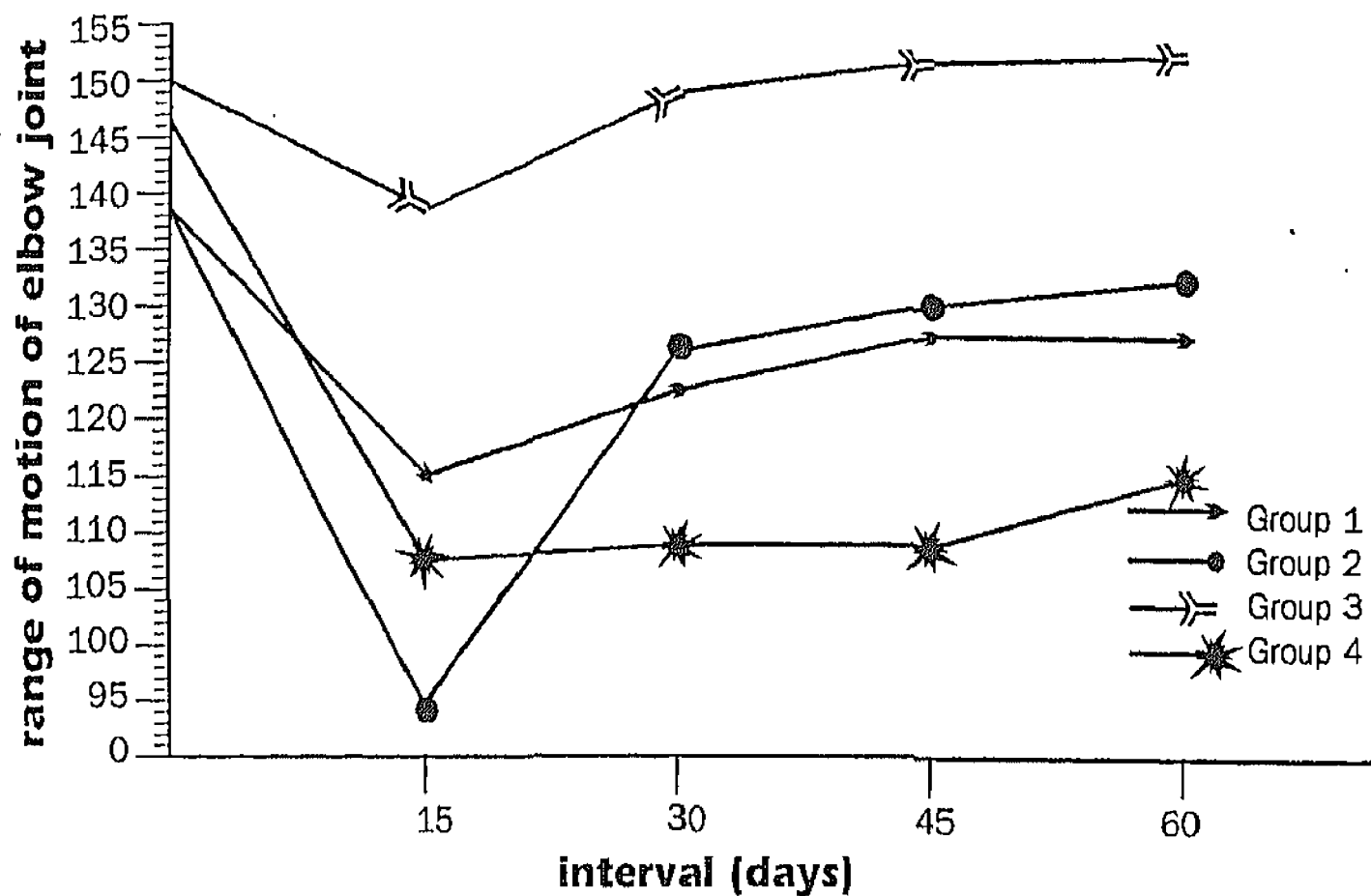


Fig 33 : Range of motion of elbow joint (Mean) at different intervals

Table 8: Range of motion of elbow joint (Mean  $\pm$  S.E.) In dogs of different groups.

Group	INTERVALS (DAYS)				
	0	15	30	45	60
1	138.75 $\pm$ 2.07	115.00* $\pm$ 3.53	122.50* $\pm$ 3.75	127.50 $\pm$ 3.75	127.50 $\pm$ 4.14
2	138.75 $\pm$ 2.72	95.00* $\pm$ 10.75	126.25* $\pm$ 4.80	130.00 $\pm$ 6.33	132.50 $\pm$ 6.49
3	150.00 $\pm$ 1.76	138.75* $\pm$ 1.08	148.75 $\pm$ 2.07	151.25 $\pm$ 3.24	152.50 $\pm$ 1.25
4	146.25 $\pm$ 2.07	107.5* $\pm$ 6.49	108.75* $\pm$ 6.21	108.75* $\pm$ 6.70	115.00 $\pm$ 8.10

\*Significantly different from the base value (P<0.05)

and onwards. However, the values for group 4 remained substantially low as compared to normal range throughout the period of observation.

### *Gross observations*

#### *Group 1*

In four animals of this group, the soft tissue healed completely without signs of any infection. The fracture site showed complete union between fracture fragment in all the animals. Plates and screws were intact and were encapsulated in thin layer of fibrous tissue in three animals (No. 7, 8 & 16) and by a thick layer in one animal (No. 4). In one animal (No. 1) in which radiological and clinical signs of osteomyelitis were seen, pus filled cavity around stainless steel plate was seen. This was encapsulated by a thick hard fibrous tissue layer. There was extensive periosteal new bony formation in this animal. However, the fracture union was complete. One animal (No. 4) showed little medial deviation of the proximal fragment in this animal. Though the fracture line extended upto articular surface of ulna, the exploration of the joint revealed clear and transparent sinoveal fluid. Sinoveal fluid showed no change in any of the animals.

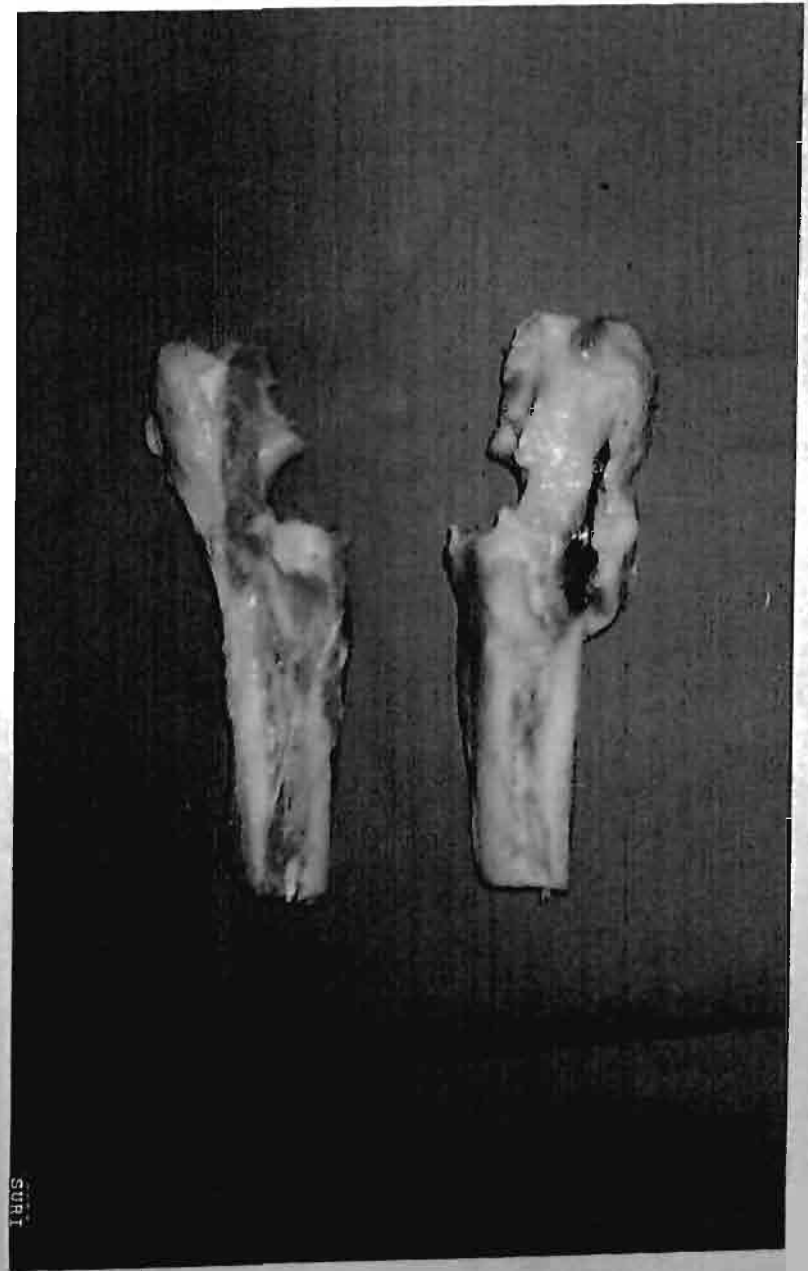
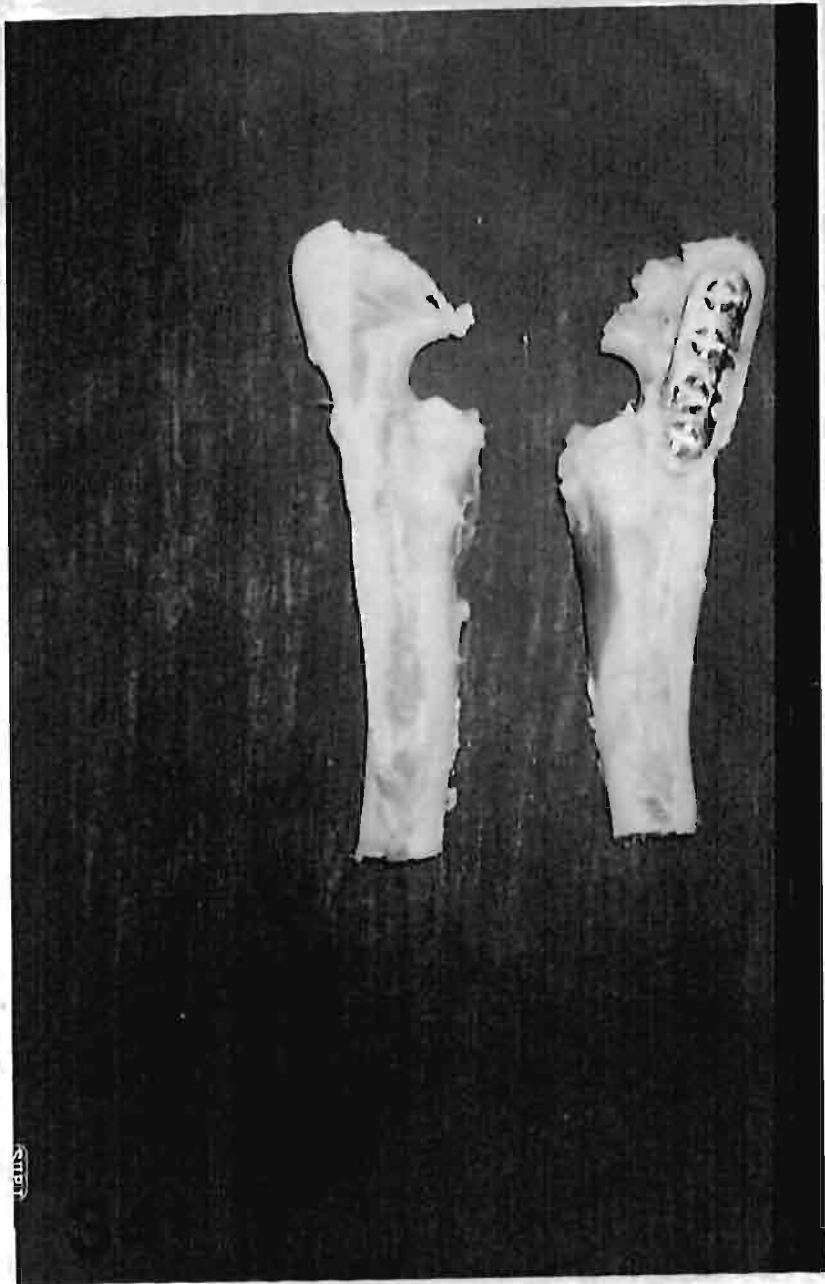
#### *Group 2*

In this group also, there was complete healing of soft tissue in all the animals. Union of fracture fragments was seen in all the animals with little callus formation. There was little serosanguinous exudate near insertion site of wire in two animals (No. 3 & 9) and pins in four animals (No. 3,6,9, & 10). In one animal (No. 5) in which articular surface was involved during fracture creation, turbid discoloration of sinoveal fluid was seen, however, no gross change in the articular cartilage was seen. The tension band wire was embedded partially in the periosteal new bone in few of the animals.

#### *Group 3*

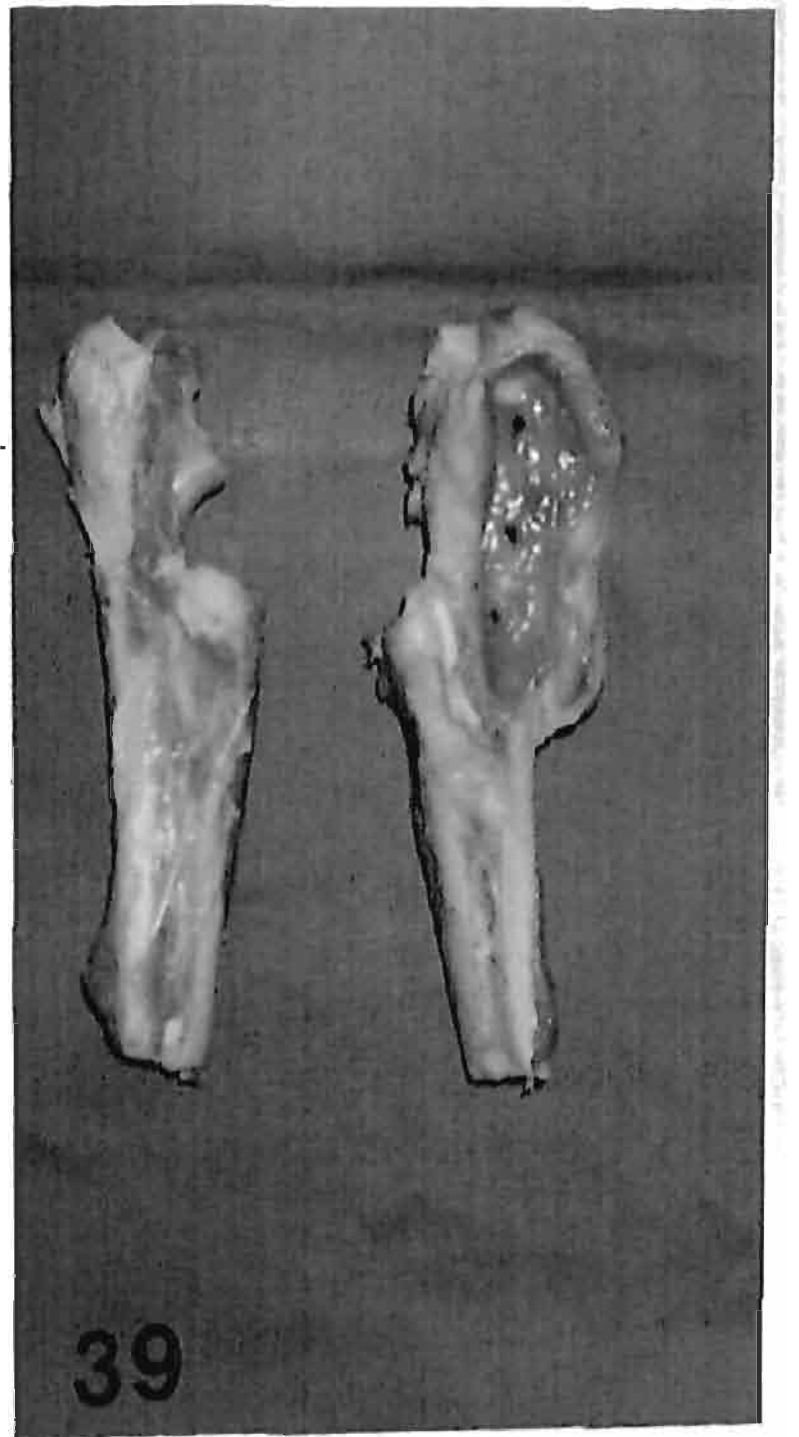
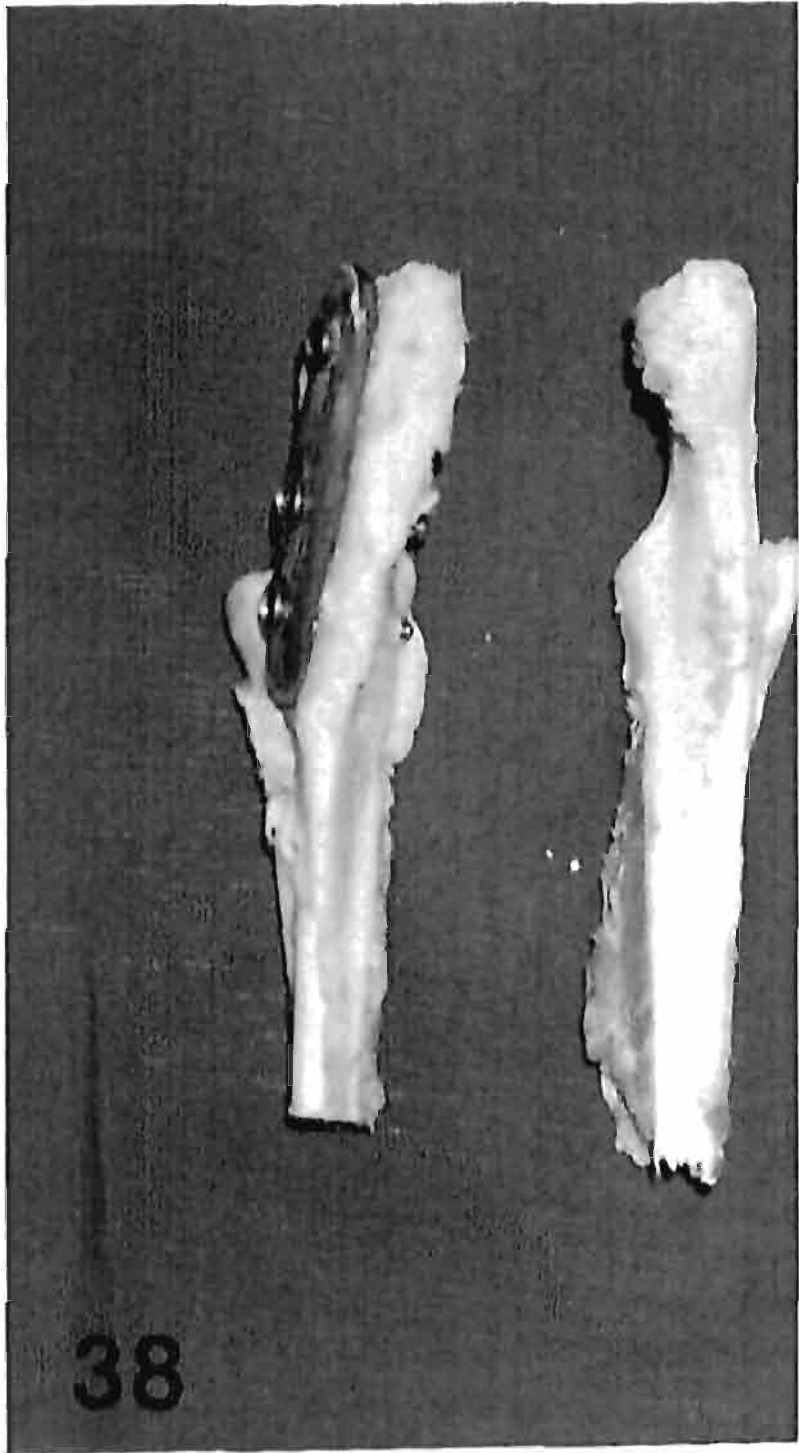
Soft tissue healed completely in all the animals of this group and the fracture union was complete. The amount of callus at fracture site was relatively less than other group.

**Fig. 34-37** Gross specimens of test bones showing complete fracture healing on day 60 in groups 1, 2, 3 and 4 respectively.



**Fig 38** Gross specimen of test bone of an animal of group 4 showing medial deviation of proximal fragment on day 60.

**Fig. 39** Gross specimen of test bone of an animal of group 4 showing excessive tissue reaction to horn plate.



Joint exploration revealed no appreciable change in the sinoveal fluid. In three animals of this group, the screws were removed with great difficulty indicating firm placement of screws and bone growth around that.

#### *Group 4*

Horn plates were encapsulated by very thick layer of fibrous tissue. The thickness of fibrous tissue was more than that seen in stainless steel plated animals. The two animals (No. 18, 20) showed complete bony union at fracture site. These animals also showed organised periosteal new bone growth along the edges of plate. The amount of new bone was considerably more than when compared to other groups. The other three animals showed non union of fracture as evidenced by mobility between the fracture fragments. Pus filled cavity around horn plate and extensive bony proliferation along the fracture edges was seen in two of these animals.

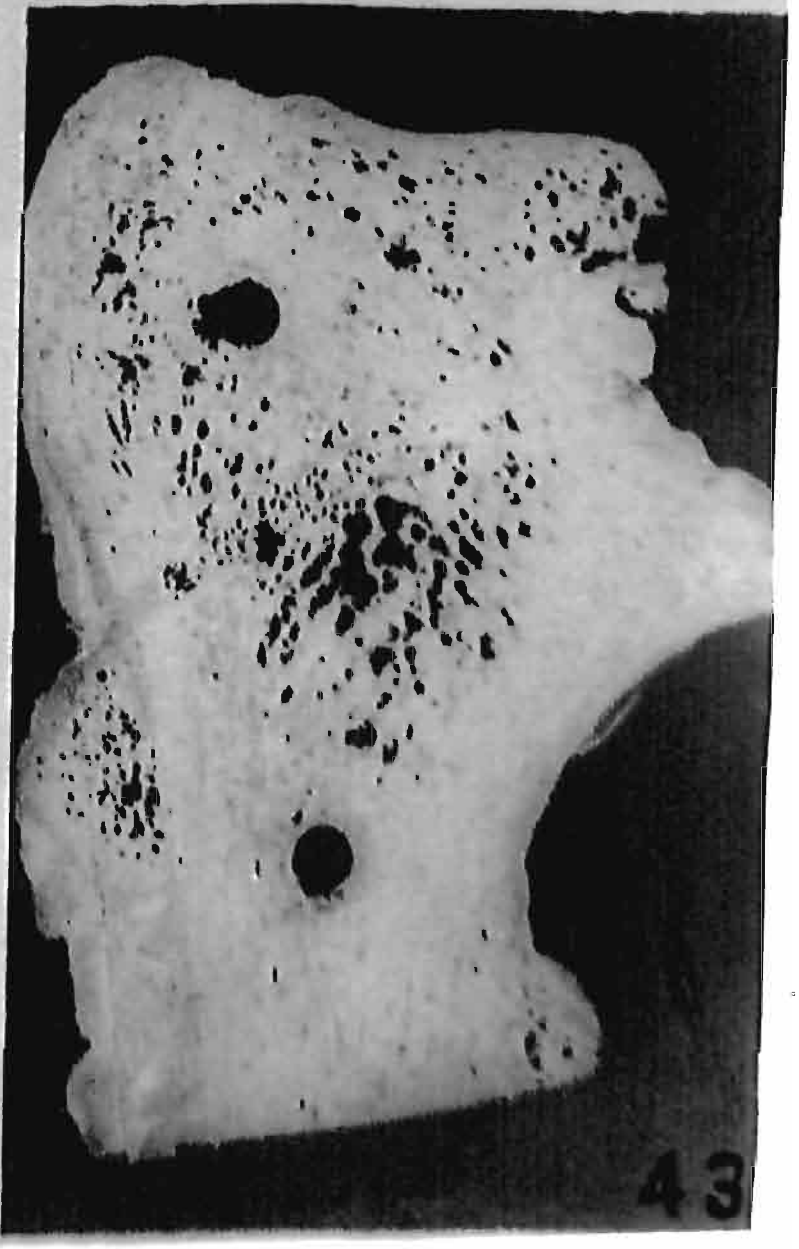
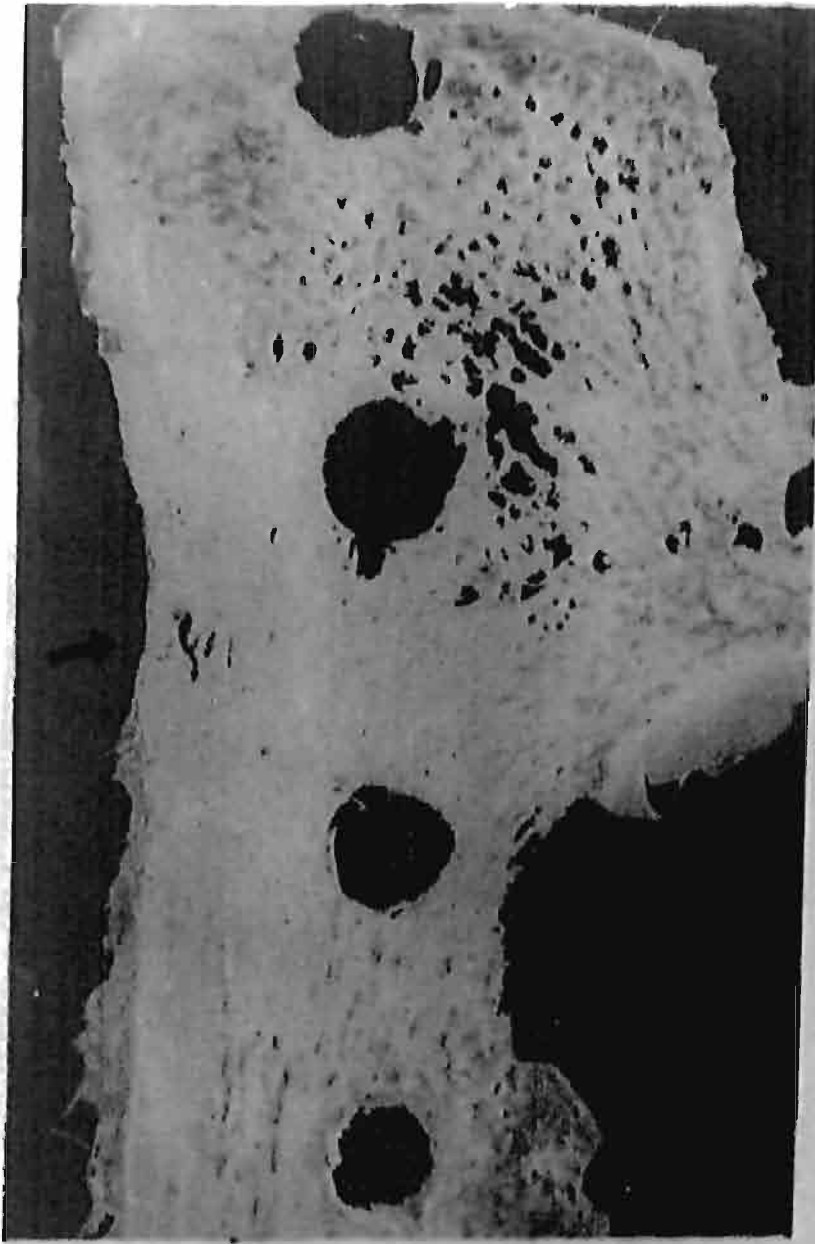
#### *Undecalcified ground section studies*

##### *Group 1*

When viewed under microscope (x10), the undecalcified ground sections of bone showed complete union at fracture site. The amount of periosteal new bone was very less except in one animal (No. 1). In general, the fracture gap was nearly completely filled with lesser dense tissue. At places, fracture line was obliterated by the newly laid bone having the density equal to the original bone on endosteal side. The cortical continuity was established with relatively less dense newly formed bone in majority of animals. In one animal (No. 1) in which clinical and radiological signs of osteomyelitis were seen, extensive periosteal proliferation was observed.

When viewed under fluorescent light under magnification (6.3x10), the newly formed bone was seen as golden yellow fluorescence. In two animals there was good fluorescence at the fracture site and the newly formed bony trabeculae penetrating the endosteal bone

**Fig 40-43** Enlarged gross photographs of undecalcified ground sections of the test bones of group 1, 2, 3 and 4 respectively, showing complete fracture healing on day 60.



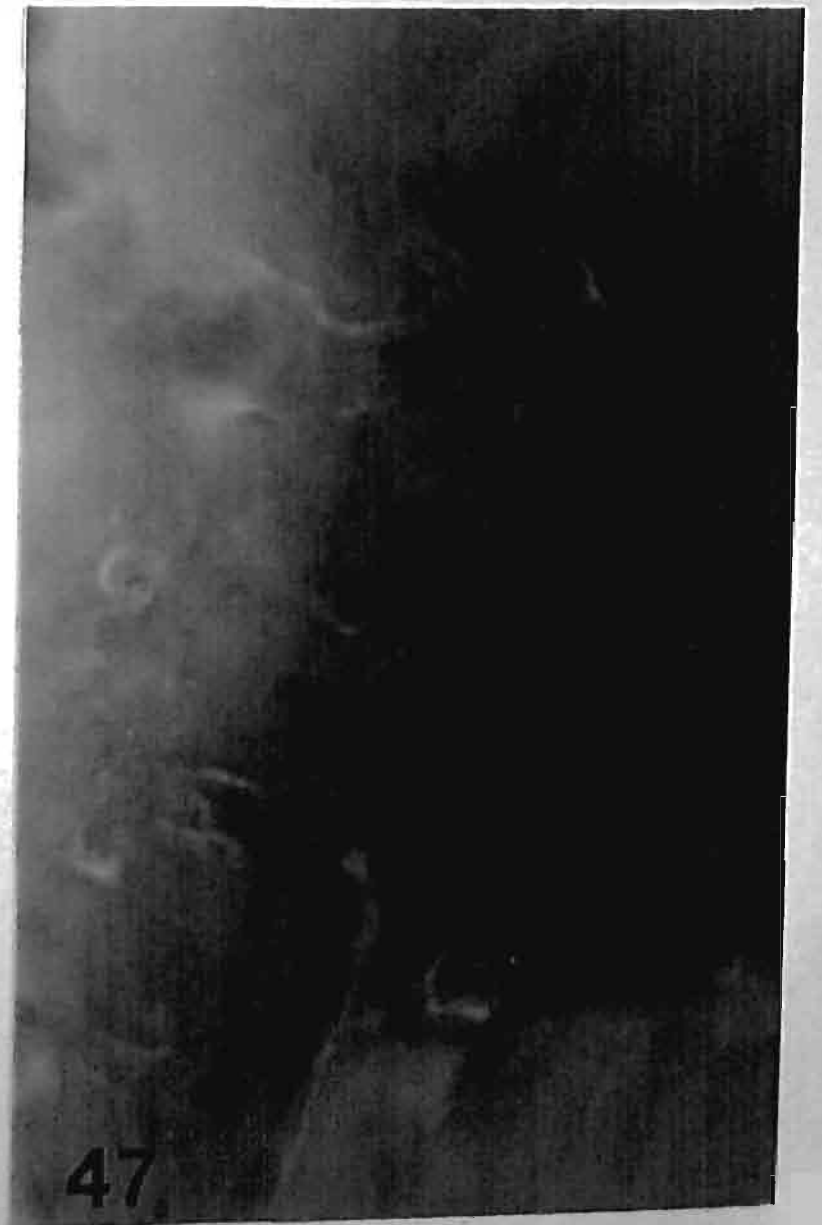
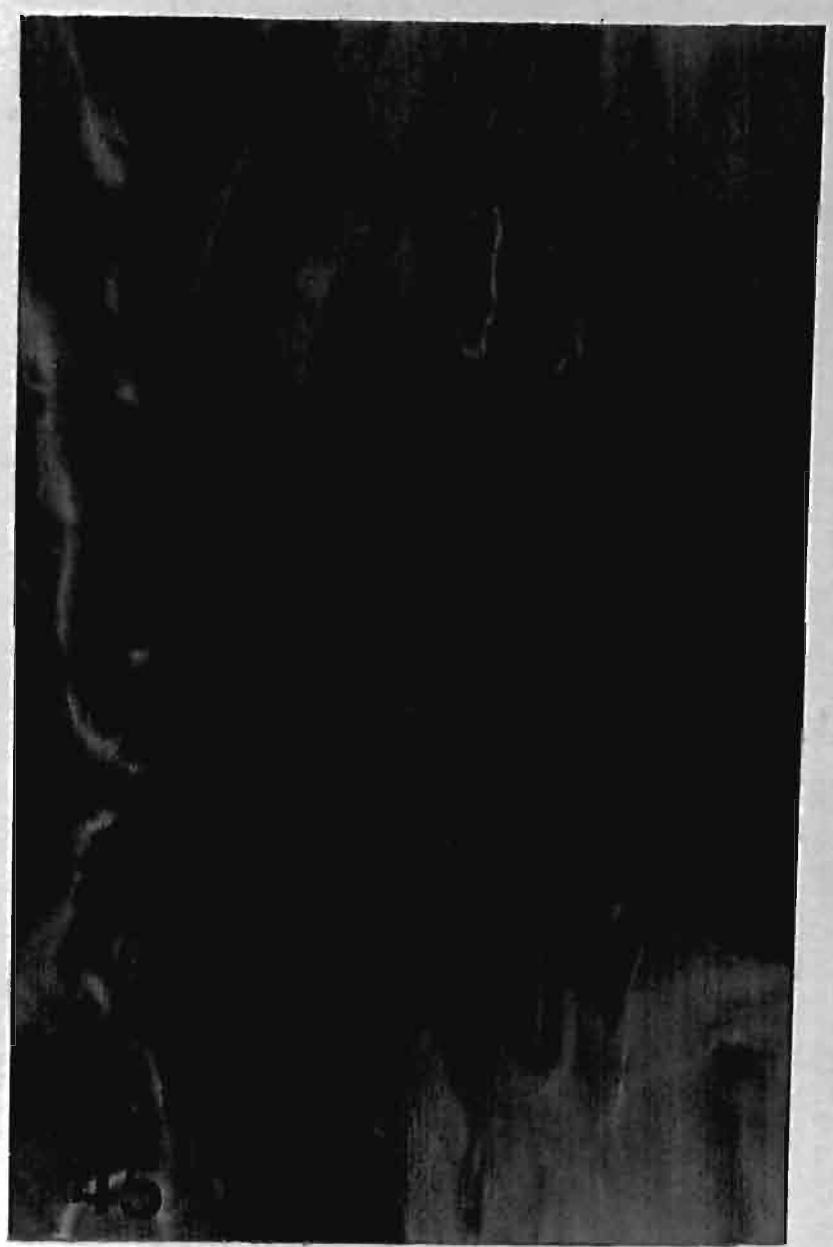
**Fig 44-47** Oxytetracycline labelled photomicrographs of fracture site in animals of group 1, 2, 3 and 4 respectively.

**Fig. 44** Photograph showing presence of very little fracture gap and new bone formation (golden yellow fluorescence) in group 1.

**Fig. 45** Photograph showing presence of numerous new bone trabeculae penetrating the either side of fragments (group 2)

**Fig. 46** Photograph showing new bone formation around fracture site as yellow fluorescence (group 3)

**Fig. 47** Photograph showing presence of large fracture gap and new bone formation. (group 4)



was observed. However, in three animals the amount of fluorescence was less and the gap was mainly filled with dark green homogenous tissue in which only few trabeculae emitting fluorescence were seen. In these animals the fracture gap was also very less. In all the animals resorption of old bone adjacent to the fracture site and its replacement with new bone as evidenced by presence of numerous resorption cavities was observed.

### *Group 2*

In this group also, there was complete union and the fracture gap was completely filled with relatively lesser dense new bone. Caudally the fracture line was less dense and visible more clearly whereas cranially it was obliterated by newly laid bone having the density equal to the surrounding endosteal bone. The amount of periosteal new bone was relatively more in this group and it was more true on caudal surface of fracture. Periosteal new bone was invariably embedded by the tension band wire partially at the site of wire crossing over.

Under fluorescent light, relatively larger fracture gap than that in group 1 was observed. The gaps were completely filled with golden yellow new bone and the amount of fluorescence was considerably more as compared to that in first group. Newly formed bony trabeculae penetrating the fracture ends were seen in all the cases. Resorption and replacement of bone edges with newly formed bone was evidenced by presence of resorption cavities.

### *Group 3*

Observations such as complete bony union and presence of more periosteal new bone on caudal aspect of fracture were comparable to those of group 2. The cranial half of the fracture line was completely obliterated by newly formed bone and the caudal half of the fracture line was faintly visible. Under fluorescent light, fracture gap was very less except in one animal (No. 11). It was considerably large and filled with relatively less new bone. In general the amount of new bony fluorescence with good number of trabeculae was comparable to group 2.

## *Group 4*

The undecalcified ground sections revealed complete bony union in two animals (No. 18, 20). The fracture line was clear and filled with relatively less dense tissue as compared to other groups. There was also extensive periosteal new bony exuberance on posterior aspect of fracture site.

Under fluorescent light extensive new bone formation evidenced by golden yellow fluorescence was seen in these animals. The fracture gap was relatively larger than that in other groups but was filled completely with new bone. New bony trabecular pattern and presence of resorption cavities were also similar as those in other groups.

## *Histopathological studies*

The decalcified microscopic sections of the fractured bone repaired with stainless steel plate showed bridging of fracture gap by periosteal and endosteal new bone. The outer side of periosteal callus was mainly formed by fibroblasts and fibrocytes, whereas, inner part showed extensive chondroblastic proliferation and intermittent bony deposition replacing the cartilagenous tissue indicating endochondral ossification. There were numerous resorption cavities at the fracture site indicating remodeling process. In one animal (No. 1) where clinical and radiological signs of osteomyelitis were seen, extensive mononuclear infiltration was observed. In another animal (No. 4) in which articular surface of bone was involved, dense fibrous tissue covering the defect in articular surface (cartilage) was observed.

In group 2, where tension band wiring was done, the histopathological changes were more or less the same as those of group 1.

In group 3, where cancellous screw was used to fix the fracture, three animals showed complete union both at the periosteal side as well as on endosteal side with no

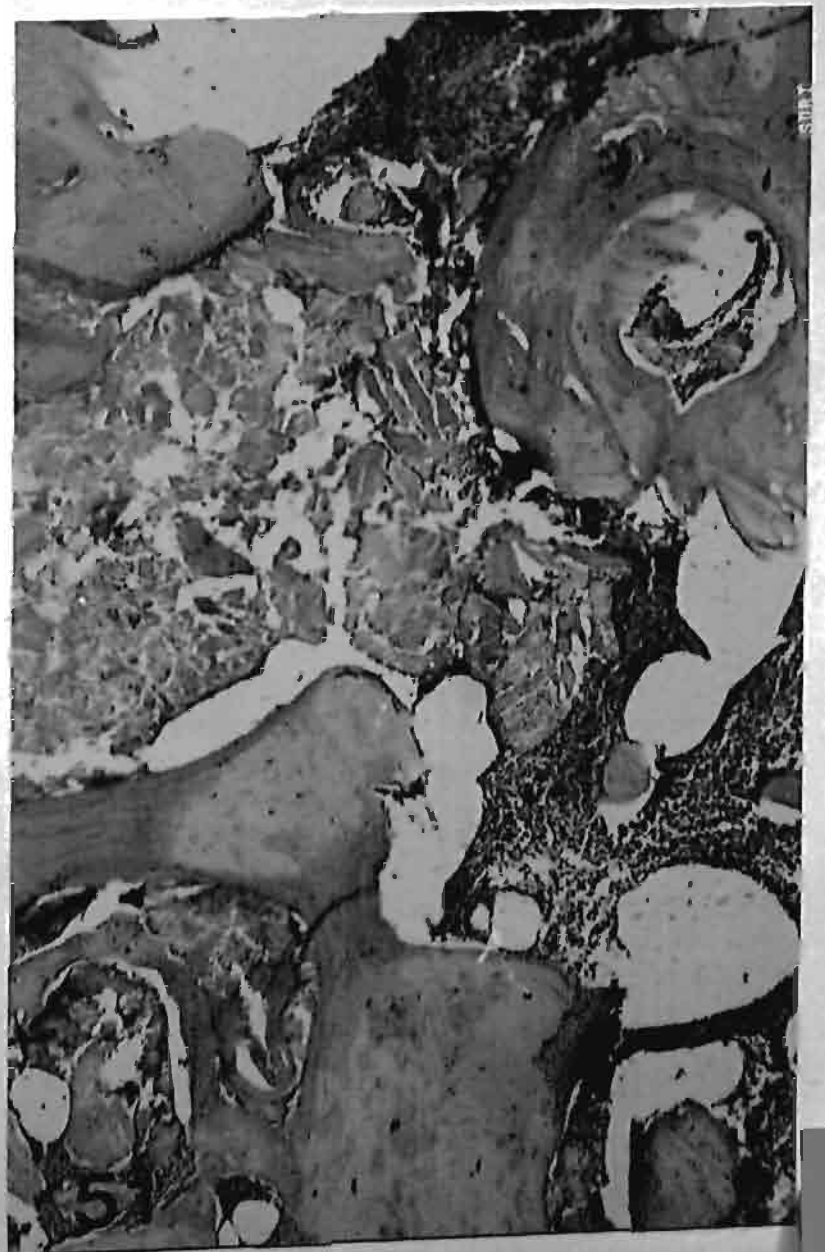
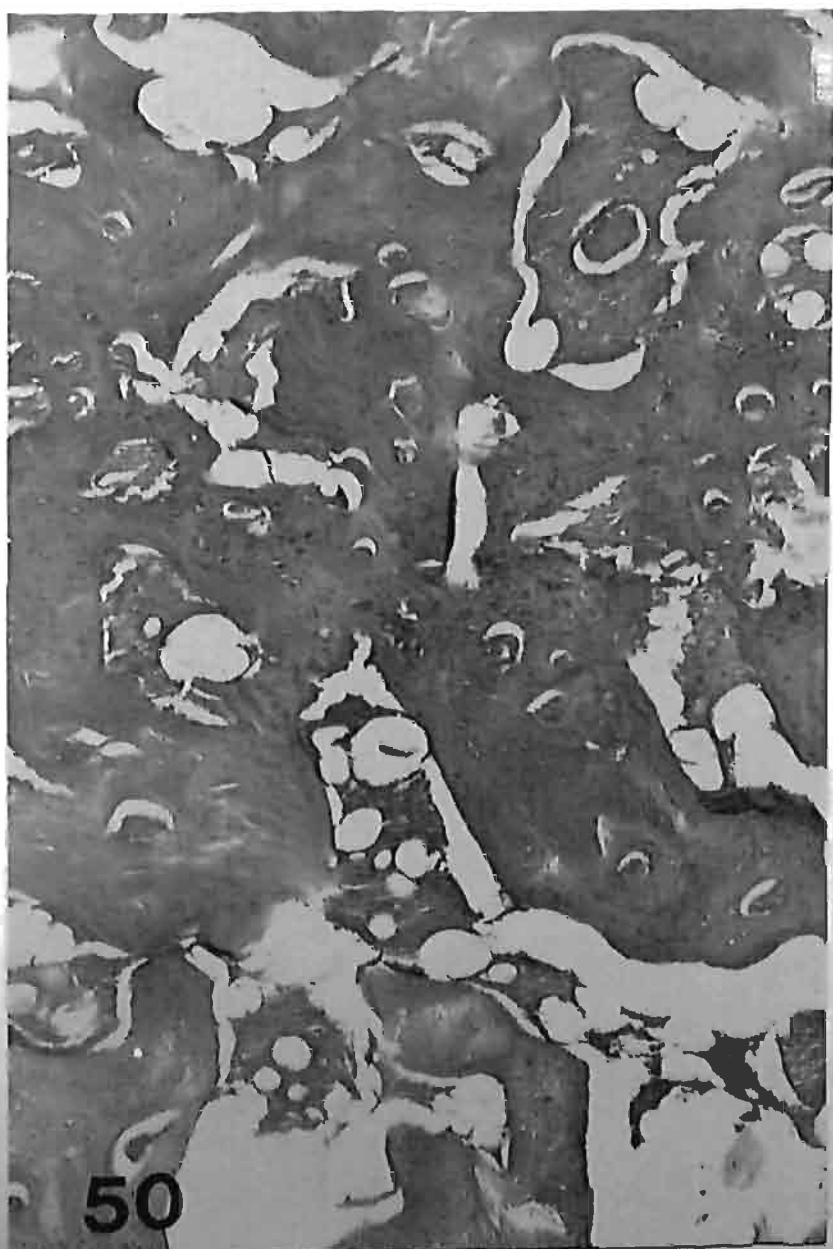
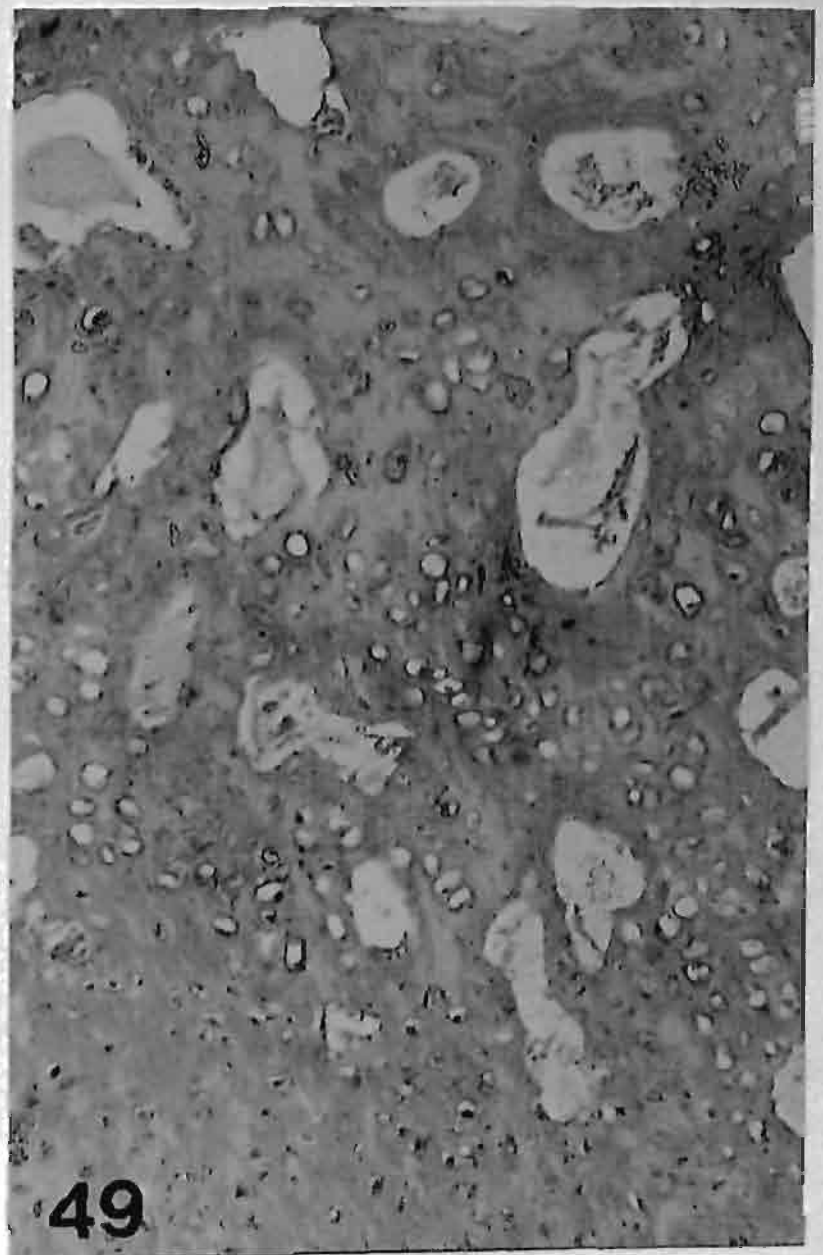
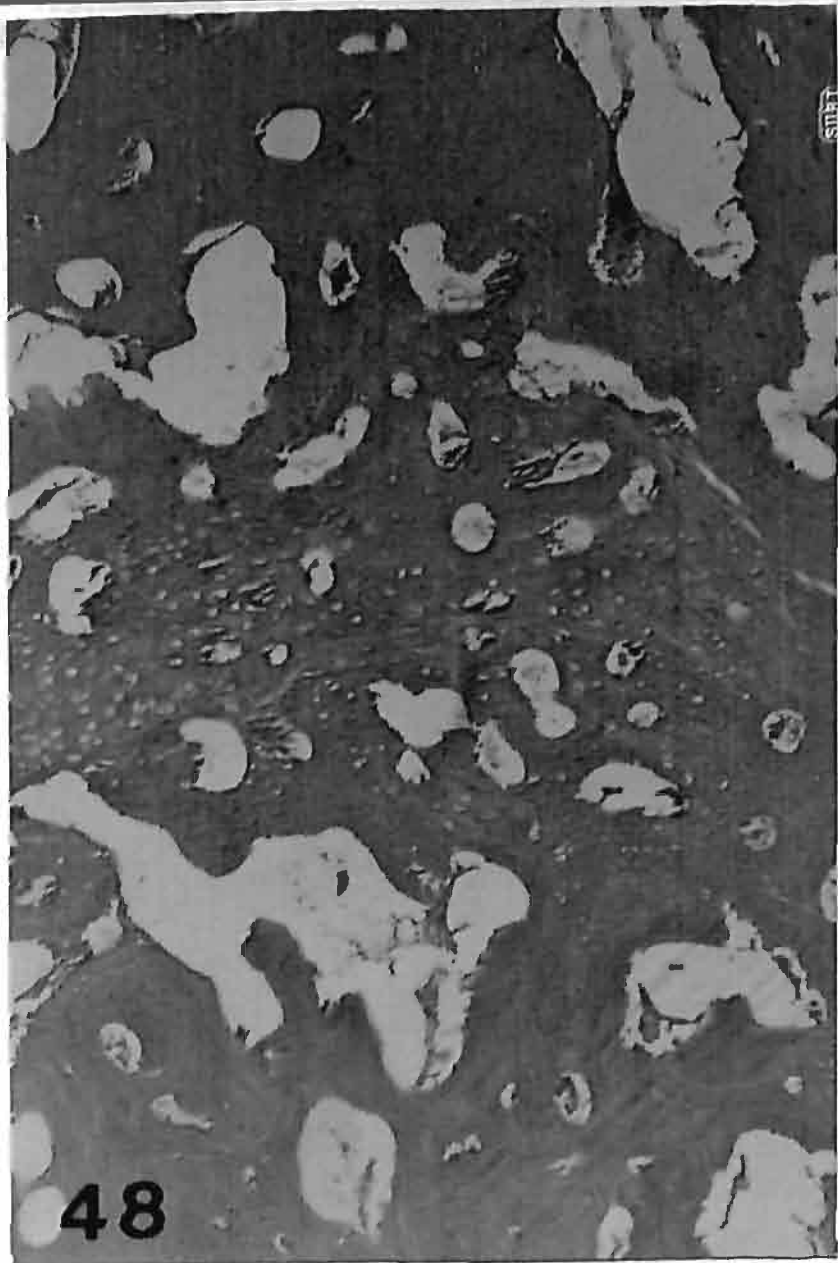
**Fig. 48-51** Photomicrograph of fracture site showing different stages of fracture healing at day 60 in animals of group 1, 2, 3 and 4 respectively. (H & E stain.)

**Fig. 48** Photograph showing chondroblastic activity at fracture site in group 1. (63X)

**Fig. 49** Photograph showing chondro-osteoblastic activity at fracture site in group 2. (126X)

**Fig. 50** Photograph showing chondrocytes getting calcified at fracture site in group 3. (63X)

**Fig. 51** Photograph showing osteolysis and diffused mononuclear cell infiltration at fracture site in group 4. (63X)



evidence of fracture gap. In remaining two animals the advanced stage of healing was evidenced by foci of chondrocytes which was being replaced by bone at places.

In group 4, where horn plates were used in fracture repair, the osseous union was evident, though it was not in orientation with either fragments. The amount of fibrous tissue was more on periosteal side. The fracture line was clearly visible with the presence of fibrocartilagenous tissue mainly. There was diffuse mononuclear cells deposition in all the animals. Desquamation of articular cartilage and lysis of subchondral bone was observed in one animal (No. 22) in which fracture line extended up to the articular cartilage. In this animal the fracture site was filled with fibrous tissue with no evidence of cartilagenous tissue.

# Discussion

## DISCUSSION

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Among the various domestic animals, dogs are more likely to suffer from automobile accident or falling from a height due to their agile temperament. Hence, fracture is one of the most common surgical conditions presented to veterinary surgeon (Phillips, 1976; Mayer, 1978; Newton 1985). Since, direct trauma in such injuries is rarely delivered in a calibrated amount to a specific place, the resultant fracture is rarely predictable (Newton, 1985) and often presents some unusual and complicated fractures. Olecranon fracture is one such type of fracture which is complicated by the presence of a distractive pull by the strong tendon on its proximal part. In the present study animal models for olecranon fracture in dogs were prepared which simulated the extra-articular fracture of olecranon seen frequently in clinical cases. These models were also identical to olecranon osteotomies which is usually done to approach distal humeral condyles and elbow joint for various orthopaedic conditions. The variables which could influence the fracture management such as surgical approach, the surgical team and postoperative management were also kept constant in all the animals to evaluate different techniques of olecranon fracture fixation.

The general anaesthesia induced and maintained by thiopental sodium in diazepam premedicated dogs was found satisfactory for the whole duration of surgery. Only in few instances where duration of surgery was prolonged, repeated doses of thiopental sodium were given.

The lateral approach used in this study to reach olecranon was a standard technique. This did not pose any problem and proper visualization of shaft of olecranon could be possible after blunt dissection of extensor carpi ulnaris.

### *INTRAOPERATIVE OBSERVATIONS*

In animals of group 1 application of the four holed venable stainless steel plate (3

cm. long) was uneventful except that the maintenance of alignment during fixation of first two screws (one each in proximal and distal fragment) posed some problem. Afterwards two screws in each fragment could be fixed easily.

Tension band wiring in animals of group 2 required maximum time for fixation (56 min), tissue manipulation was relatively more and application was also technically more difficult when compared to other techniques used in this study. This was because of the angle of insertion of the Steinmann pins which was very critical to avoid the penetration of the articular surface of ulna as well as to engage the opposite cortex of the distal fragment to provide better compression by tension wire. Further, since proximal fragment was short and deviated medially, anatomically it was difficult to keep the alignment while inserting the pin. The pins driven into the medullary cavity of distal fragment, however, could fit snugly and provided better stability at fracture site. Pins were bent caudally near the point of insertion and cut. The cut ends were then rotated cranially so as they lie against the triceps tendon and provide better anchorage to tension band wire. The displacement of proximal fragment was followed during this process in some cases because the convex bent surface of pins exerted a spring action along the shaft of distal fragment and consequently the proximal fragment was displaced anteriorly. In such cases, readjustment of pin position or replacement with a new pin had to be done in order to achieve a better alignment. This resulted in extended duration of surgery and more soft tissue trauma. The cranial bending of pins before cutting the ends is not preferred because the cut ends will not lie against the tendon and will cause the irritation to the overlying tissue (Probst, 1993).

Application of tension band wire was also associated with slight loosening while bending the cut ends of the twisted knot towards bone surface as also reported by other worker (Wilson, 1985). In this study the loosening of wire in no way affected the stability of fracture fixation.

Fixation of olecranon fracture with cancellous screw (group 3) was easiest, less time

consuming and required minimal soft tissue manipulation as compared to other techniques.

In group 4, where horn plates were used for fracture fixation, only one screw could be placed in proximal fragment as drilling of two holes close to each other may predispose splitting of horn plate between the holes during tightening the screws. Splitting of horn plates has been reported during tightening the screws when the hole was very near to edges and when the two holes were close to each other (Aithal, 1996).

### *Clinical Observations*

Almost all the animals of group 1 started bearing weight on the test limb soon after they recovered from anaesthesia. This suggests that the fracture reduction and fixation was good and also that the animals were under the influence of sedative and analgesic drugs given pre and postoperatively. However, as the signs of inflammation became intense, the weight bearing was also affected after 24 hours of surgery. In fracture cases stage of inflammation begins immediately after the fracture and persists until initiation of cartilage or bone formation (Arnoczky *et al.* 1985). In animals of this group, the signs suggestive of inflammation on its peak were observed on day 3 postoperatively. Thereafter, the inflammation subsided gradually by 15 POD. This suggests that process of periosteal callus formation had initiated at this stage. In all but one animal surgical wound healed by first intention. One of the animals of this group, which showed severe and prolonged inflammation and oedema and intense lameness in the initial stages, later developed osteomyelitis. This might be attributed to a breach in asepsis during surgery. This indicates that prolonged inflammation and oedema coupled with non weight bearing are probably the early signs suggesting the possible development of osteomyelitis. In another animal where fracture line extended the articular surface of ulna, initial intense lameness was observed. That might be due to pain during joint motion and delayed onset of fracture healing. The sinoveal fluid is reported to contain fibrinolysin which dissolves the blood clot and hence delays the early stages of fracture healing (Cruess & Dumont, 1985). The weight bearing improved steadily in all the animals except the one which developed osteomyelitis.

In group 2, though animals showed good weight bearing immediately after recovery, inflammatory swelling and pain appeared faster as compared to animals of other groups and this was manifested by intense lameness during subsequent postoperative period. This may be attributed to the extensive soft tissue manipulation and trauma during fracture fixation with tension band wiring. However, animals showed good improvement in weight bearing as inflammatory phase ended and attained near normal level by the end of observation period indicating normal course of healing. Two animals where fracture line extended upto the articular cartilage showed prolonged lameness and slower recovery rate. In one of these animals distraction of proximal fragment suggestive of fixation failure was seen on day 1 radiographically. In other animal, the fracture fixation was maintained throughout the observation period and there was gradual improvement. These observations suggest that involvement of articular surface in fracture of olecranon are relatively difficult to manage in comparison to those where articular surface was not involved. Further, extra care is needed in the application of tension band wire to prevent distraction of proximal fragment during postoperative period in such cases. In one animal, where oozing of serosanguinous exudate was observed on day 40, the radiograph taken on day 45 showed breakage of tension band wire. In this animal local irritation caused by the broken ends of the wire did not affect the fracture healing process.

In group 3 only the mild degree of inflammation appeared that too subsided faster than any other group. Further no oedematous swelling or wound dehiscence was observed. This was because fixation of cancellous screw caused minimum trauma and provided optimal level of fixation. This was also supported by early and good weight bearing in animals of this group.

In group 4, weight bearing was comparable to all other groups in immediate postoperative period suggesting adequate fixation of fracture by horn plate. However, the inflammation, pain and oedema was maximum in this group of animals which started earlier as in group 2 and persisted for relatively longer period. This shows that horn plate is not as

inert as stainless steel plate. The thickness of horn plate was also more than stainless steel plate and considering that very little muscular and subcutaneous tissue is present at the surgical site to cover up the horn plate, more tissue reaction was anticipated in this group of animals. This resulted in severe wound dehiscence in most of the animals accordingly. Severe soft tissue inflammation and infection was also reported by many workers who have used horn plates for fixation of different fractures in dogs (Singh, 1988; Shivprakash, 1995; Aithal, 1996). The weight bearing was poorest in this group and severe muscular atrophy was seen. Prolonged poor weight bearing may be attributed to inadequate level of fixation due to placement of only one screw in the proximal fragment, flexible nature of horn plates and the persistence soft tissue inflammation and infection for a longer period. In any fracture fixation with plate, attempts should be made to put atleast two screws in each fragment in order to achieve a satisfactory fixation (Leonard, 1961). Therefore, single screw and the flexible horn plate might have allowed more motion of the proximal fragment resulting in pain and lameness. Slight movement of fracture site due to the flexible nature of horn plates has also been reported by Sarkate (1989) and Shivprakash (1995) in the repair of radial, metacarpal, tibial and femoral fractures using horn plates. Similar complaints of pain were also observed in human patients fixed with semi-rigid carbon-fibre reinforced (C.F.R.C.) plastic plates (Tayton and Bradley, 1982). The increased inflammation observed in the initial postoperative days leads to adhesion formation, which restricts or prevents the normal gliding motion in adjacent muscles and tendons (Schatzker, 1982) leading to decrease in weight bearing. The presence of infection at the fracture site also delays the healing process (Andriole, 1973). These all factors had their combined effects on the functional uses of limb and that resulted in prolonged lameness in the animals of this group. Few animals of this group showed a continuous gradual improvement in weight bearing after 30 POD. That suggests that despite presence of infection the fracture healing might have started.

The increase in heart rate, respiration rate and rectal temperature in the early postoperative period in all the animals of all four groups is the normal response of body to surgical stress. There was no marked difference in values of these parameters in the animals

which developed osteomyelitis at later stage when compared to those animals which recovered without any complication. Charles *et al.*, (1984) and Singh (1988) also reported that aside from lameness and disuse atrophy of the muscles, the dogs having infections never developed pyrexia in such fracture cases.

### *Radiographic Observations*

Mediolateral and antero-posterior radiographs taken at different intervals helped to assess the placement of plates, screws, pins and wires and the healing process at the fracture site in different group of animals. Radiographic evaluation of fracture healing in both the views was easier in group 2, 3 and 4 where tension band wiring, cancellous screw and horn plate were used respectively and difficult in group 1 where stainless steel plate and screws were used to fix the olecranon fracture. The radio- opaque stainless steel plate (group 1) blocked the view of olecranon in lateral views. Horn plates provided better assessment of fracture healing because of its radiolucency. This radiolucency of horn plate is due to its negligible amount of inorganic components (Singh, 1986). Other workers have also reported the advantage of horn plates in the radiographic evaluation of fracture healing in cattle (Singh, 1986; Sarkate, 1989) and dog (Singh, 1988; Dubey *et al.*, 1992; Shivprakash, 1995, Aithal 1996).

In group 1, plates and screws maintained their position throughout the period of observation in all the animals. This suggests that the plates were symmetrically placed in reference to the bone axis and also that the fracture reduction was perfect and no gap was present. Asymmetric location of plate in reference to the neutral axis of bone and gap between fracture ends places the plate at the mechanical disadvantage and it is susceptible to failure due to bending and torque (Smith, 1985). Normal course of healing was evidenced by appearance of periosteal new bone around day 15/30, bridging of the fracture gap at day 45/60 and initiation of remodeling process of new bone at day 60 in majority of animals. This suggests that application of stainless steel plate on lateral aspect of olecranon is capable of providing adequate fixation required for fracture healing. Other workers have also

reported that plates provide most stable form of fracture fixation and they are effective in neutralizing all forces that commonly act on fractures (Schwarz, 1991).

In one animal in which clinical signs of osteomyelitis was seen, radiological signs also became clear as early as day 15. Extensive periosteal proliferation was seen along the whole length of olecranon on 15th POD. Lysis of bone and sequestrum formation was seen on day 30 postoperatively. At day 60, extensive bone resorption, periosteal elevation with exuberant periosteal new bone formation was observed in this animal. Similar findings have been reported in cases of bone infection by Charles *et al.* (1984) and Daly (1985).

In group 2, the pins and wires remained fixed in their respective position in two animals. In remaining animals bending of pin (Animal No. 5), breakage of wire (Animal No. 9) and stretching of wire (Animal No. 10) were recorded at different intervals. The bending of pin may be attributed to insufficient traction by the tension wire to counteract the distractive pull of triceps tendon which are exerting severe bending forces on the pins. Moreover the articular surface was also involved in that animal hence the articular margin of ulna might have served as a fulcrum and predisposed the pins for excessive bending forces (Denny 1985). Breakage of wire at its insertion site in the distal fragment may be attributed to cyclic stress acting there especially if the wire is loose. However, stretching and breakage of wire did not result in any fracture fixation failure and these animals exhibited normal courses of *fracture healing but where pin was bent (one animal) anterior displacement of proximal fragment with an appreciable fracture gap was observed.* This animal remained lame throughout the observation period inspite of apparent fracture healing and bridging of gap by 60th P.O.D. Majority of animals showed normal course of healing as in group 1 indicating successful fixation of olecranon fracture with this technique.

In group 3, all the animals showed *proper fixation of fracture by cancellous screws* which maintained their position as such throughout the observation period. The appearance of callus and the bridging of fracture gap was faster than that of other groups indicating rigid fixation and faster healing.

In group 4, plates and screws maintained their positions in three animals whereas

in two animals placement of plates and screws were disturbed resulting in distraction of proximal fragment anteriorly and a large fracture gap. Among these two animals, breakage of bone in proximal fragment near the fracture line in one animal and the deviation in the direction of proximal screw in another was observed. Breakage of bone suggests that drilling of screw hole very close to fracture line predisposed the bone for breaking under distracting forces. The deviation in the direction of screw in another animal shows poor resistance of single screw against tensile forces. The flexible nature of horn plate might also have helped the deviation.

The two animals of this group who showed good recovery and proper weight bearing also showed normal course of fracture healing radiographically. However, the amount of the periosteal new bone was more in these animals when compared to animals of other groups. This may be attributed to slight movement at the fracture site. The amount of external callus is directly related to the degree of stability at the fracture site (Meckibbin, 1978). The horn plate being semi-rigid in nature allows greater movement at fracture site when compared to stainless steel plate.

Extensive periosteal reactions were observed in remaining three animals indicative of infection. One animal showed clear signs of osteomyelitis such as mottled appearance of periosteal new bone on day 30 and resulted in non-union. Other two animals also showed extensive periosteal proliferation which subsided in one animal after removal of horn plate and continued with other clinical signs of osteomyelitis in another animal where horn plate was not removed. High infection rate has also been reported by other workers who have used horn plate for fracture fixation (Shivprakash, 1995).

### *Functional status of elbow joint*

All the extensor muscles of elbow joint i.e. triceps brachii, tensor fasciae antebrachii and anconeus insert on the olecranon process of ulna (Skerritt & Lelland, 1984). Therefore, fracture of olecranon will invariably impair the normal function of these muscles resulting in restricted extension and flexion of elbow joint and diminished ranged of motion in the

affected limb. The principle objectives of fracture management are to bring about fracture union and to restore normal function of the limb (Boudrieau, 1991; Fossum and Hulse, 1992). Therefore, extension and flexion angles and range of motion of the elbow joint were recorded at different intervals to evaluate and compare the functional status of elbow joint in different groups.

The extension and flexion angles of the normal elbow joint did not show much variation between different groups (table 6 & 7). Newton (1985) also reported similar range of extension angles of elbow joint in dogs. The flexion angles, however, was recorded relatively less in some of the animals in comparison to that reported by Newton (1985).

The decrease in the normal extension and flexion angles in all the animals of different group on 15th POD could be attributed to inflammation and pain in early postoperative period. The decrease was maximum in animals of group 4 and minimum in group 3 and was directly related to the severity of inflammatory reactions in different groups. The recovery was also faster in animals of group 3 and slow in group 4.

These observations supports the clinical and radiological findings. In animals where recovery in clinical signs was faster and fracture fixation was maintained, early recovery of joint function was seen. In animals where anterior distraction of proximal fragment was seen in postoperative radiograph, the range of motion of elbow joint was also affected. Therefore, recovery of joint motion in fracture cases depends on extent of soft tissue trauma and status of fracture reduction and fixation.

### *Haematological and biochemical observations*

An increase in the total leukocyte count (TLC) recorded in the immediate postoperative period was the normal body response to stress and inflammation that invariably followed after surgery. In fracture cases, the stage of inflammation is said to begin immediately after fracture and persists until initiation of cartilage or bone formation (Arnoczky *et al*, 1985).

Subsequent drop in TLC was indicative of resolution of inflammatory process.

All the animals showed a significant relative increase in neutrophils count and decrease in lymphocyte count in immediate postoperative period in accordance with the normal response of body to any inflammatory process. The neutrophils have been recognized as the first cellular defence of the body and neutrophilia along with leukocytosis is generally observed during inflammation (Coles, 1974; Schalm *et al.*, 1975). An increase in TLC and neutrophilic count has also been reported by other workers after fracture fixation (Shivprakash, 1995; Aithal, 1996).

During fracture healing and in diseases of bone increase in osteoblastic activity and alkaline phosphatase levels are related because the rate of release of enzyme into the serum will exceed its rate of inactivation (Hill and Sammons, 1967). In this study, an increase in serum alkaline phosphatase activity showed an increasing trend till day 30 postoperatively in all the four groups. This suggests the ongoing osteoblastic activity and normal fracture healing. Several other workers have also reported the increased serum alkaline phosphatase level after fracture repair in dogs (Pandey and Udupa, 1981; Shivprakash, 1995; Aithal, 1996).

### *Gross Observations*

The stainless steel plates (group 1) and the horn plates (group 4) were encapsulated in fibrous tissue in all the animals. The fibrous encapsulation of horn plates was relatively thicker in comparison to that of stainless steel plates. Rhinelander *et al.* (1971) also observed encapsulation of implants of surgical metals and acrylic cement. They opined that the fibrous membrane developed as an avenue for regenerative extraosseous vessels to the cortex. Similar observations have also been made by other workers who have used stainless steel plate and the horn plates for fracture repair (Singh, 1986; Singh, 1988; Shivprakash, 1995). More pronounced reaction of soft tissue as well as osseous tissue at the site of its contact suggests less inert nature of horn plate. Further, presence of infection

in the soft tissue in most of the animals of this group might have incited more soft tissue reaction around the horn plates.

In group 1 good fracture healing with little callus formation was suggestive of excellent fixation provided by stainless steel plate. In one animal, however, excessive new bone formation was due to presence of infection as evidenced by radiographical observations.

Good healing was also observed in animals of group 2 like group 1. In few animals however, presence of serosanguinous exudate around the insertion site of pin and wire were suggestive of continuous irritation to the overlying tissue by the sharp ends of implant. Overall good fracture healing indicate adequate level of rigid fixation provided by tension band wiring.

In group 3, the less amount of periosteal new bone indicates rigid fixation and advanced stages of fracture remodeling. The difficulty in removing the screws were indicative of good bone growth around the threads and shaft of screws. Prieur and Sumner Smith (1984) also reported that the removal of cancellous screws that are not fully threaded may be difficult or lead to screw fracture due to deposition of solid bone around the non threaded portion of the shaft.

Gross observations of test bones in group 4, also supported the clinical and radiological findings. The complete bony union was seen in two animals that suggests that horn plate is capable of providing optimal level of fixation required for fracture healing. The presence of pus filled cavity around horn plate in majority of animals of this group suggests presence of infection in soft tissue. The mobility between fracture fragments observed in three animals was suggestive of delayed/non union. In two of these cases fixation failure resulted in anterior displacement of proximal fragment whereas in one animal signs of osteomyelitis were present.

## *Undecalcified ground section studies*

The undecalcified ground sections of test bone prepared as per the method described by Parasanalli (1988) were found useful to assess the extent of fracture healing. The labeling of new bone by oxytetracycline dihydrate also helped to quantify the extent of new bone formation. The labeled new bone gave golden yellow fluorescence under fluorescent light microscope and provided the useful details about the fracture healing process.

In animals of all the groups, the new bone formation and extent of fracture healing was more in the inner cancellous bone than the outer cortex. This is due to presence of many points of bone contact which are rich in cells and blood supply (Crues and Dumont, 1985). The density of new bone was also invariably lesser than the original bone in all the animals. This is reported to be due to difference in mineral composition and crystal size of new bone as compared to old bone (Lane *et al.*, 1984).

In animals of group 1, union between the fracture fragment was complete by newly formed bony tissue and the continuity of cortex was restored indicating normal fracture healing process. Under fluorescent light presence of good amount of new bone in the fracture gap, the newly formed bony trabeculae penetrating either side of endosteal bone and numerous resorption cavities supported the different stage of normal fracture healing process.

In animals of group 2, there was complete bony union between the fracture fragments indicating adequate fixation provided by tension band wiring for fracture healing. However, the fracture gap was relatively more than that in the animals of first group indicating slight distraction of proximal fragment. This may be due to slight loosening of tension band wire while bending the twist ends of wire knots towards the bone. Such loosening of wire has also been reported in cerclage wiring (Wilson, 1985).

It was interesting to note that the fracture healing was more complete on cranial aspect of fracture line when compared to that on caudal aspect as evidenced by the similar density of new bone as of the adjacent bone in the cranial aspect. This was further supported by oxytetracycline labeling studies which showed presence of relatively more number of new bony trabeculae in the cranial aspect of fracture. The cranial side of olecranon fracture is said to be under more rigid compression under tension band wiring (Bloomberg, 1993). This rigid compression might have helped the early bony union of fracture cranially.

Animals of group 3 showed excellent fracture healing on periosteal as well as on endosteal side. The fracture gap was completely filled with newly formed bone and the continuity of cortex was restored. Resorption cavities and newly formed bony trabeculae were noticed at many places and that were indicative of advanced stage of fracture healing. In this group also the better healing was observed on cranial aspect of fracture line. This suggests that bony union is good and faster under rigid compression at fracture site.

Among animals of group 4, only two animals showed fracture healing. In these animals, though the fracture gap was large, good amount of new bone formation was observed. New bony trabeculae penetrating endosteal side were seen at places.

### *Histopathological studies*

Histopathological observations further supported the radiological, enlarged gross section photography and undecalcified oxytetracycline labeling findings. As seen with other studies these findings were also indicative of normal fracture healing in majority of animals of all the groups. It also revealed that the fracture healing was faster and more complete in the inner cancellous bone as compared to cortex. It can be attributed to the availability of more osteogenic cells and blood supply (Cruess and Dumont, 1985). In majority of animals the classical fracture healing (by endochondral ossification) was seen and fibrous, cartilagenous and osseous components were present. The fracture line was identified mainly by the presence of fibrocartilagenous or chondro-osteoblastic activity at one or other place.

The presence of degenerating/calcifying cartilage forming the core of osseous trabeculae supported the findings of Ham (1969) and Turek (1983) who opined that the remnants of calcified cartilage in the core of trabeculae of cancellous bone indicated early stages of normal fracture healing. Bone forming cells are said to be derived from pluripotential mesenchymal cells of osteogenic layer of periosteum, endosteum or marrow cavity (Ham and Cormack, 1979; Brand and Rubin, 1987). Differentiation of pluripotential mesenchymal cells is affected by many factors and variable sized islands of cartilage are present in most healing fractures (Brand and Rubin, 1987).

When compared between the different groups, the fracture healing was relatively faster in animals of group 3 where advanced stages of fracture healing was seen as evidenced by near complete replacement of cartilagenous tissue by osseous tissue. These observations suggested that minimum soft tissue trauma and rigid fixation of fracture with early weight bearing are three main factors responsible for early repair of fracture as also opined by Cruss and Dumont (1985). All the animals of group 1 and 2, also showed different degree of chondro-osteoblastic activity at many places indicative of ongoing fracture healing process by endochondral ossification. Two animals of group 4, also showed ongoing healing process at the fracture site. However, presence of abundant mononuclear cells in all the animals including these two suggested infection at the site. It indicated that fracture healing can occur even in the presence of some degree of infection. Presence of infection is reported to either retard or stop the fracture healing by other workers also (Andriole, 1973).

# Summary

## SUMMARY

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This study was conducted in 24, clinically healthy adult mongrel dogs of either sex, divided randomly in to 4 equal groups. Extra articular short oblique fracture was created in olecranon in all the animals under thiopental (5%) general anaesthesia. In animals of group 1 and 4, the fracture was fixed with stainless steel plate and horn plates respectively which were applied on the lateral aspect of olecranon. In group 2, the tension band wiring and in group 3, single cancellous screw in a lag fashion was used for fracture fixation. Routine postoperative care was provided to all the animals and these animals were maintained for at least 60 days postoperatively. Different techniques of fracture fixation were evaluated and compared on the basis of intraoperative, clinical, radiological, haematological & biochemical, undecalcified ground section and gross & histopathological observations.

Among the different techniques used for fixation of olecranon fracture, the cancellous screw fixation was proved to be the easiest technique, whereas, the tension band wiring, the difficultmost. Consequently, the degree of soft tissue manipulation and duration of surgery was also minimum in animals where cancellous screw was fixed and maximum where tension band wiring was done.

Postoperatively inflammation and oedema at the site was maximum on day 3 in animals of all the groups. Inflammation was set in earlier in animals of group 2, whereas, the overall degree and duration of inflammation/oedema was maximum in animals of group 4. Skin wound healed by first intention in majority of animals. However, wound dehiscence was noticed in 2 animals of group 1 and 3 animals of group 4, which took longer time to heal. All the animals started bearing weight soon after recovery from anaesthesia but exhibited varying degree of lameness as the inflammatory reactions set in. On day 15, weight bearing was significantly less ( $P < 0.05$ ) than the normal in animals of all groups. Improvement in weight bearing was seen in subsequent postoperative period. The rate of recovery

was fastest in group 3 and slowest in group 4. Poor or no improvement in weight bearing was noticed in cases where osteomyelitis (one in group 1 and 2 in group 4) and/or implant failure (one each in group 2 & 4) was recorded.

No significant difference in heart rate, respiration rate and rectal temperature were seen among animals of different groups.

Radiographs taken immediately after surgery revealed good reduction and fixation of fracture in animals of all groups. Radiographs taken at subsequent intervals showed maintenance of initial fixation in majority of animals. However, in 1 animal of group 2 and 2 animals of group 4, anterior distraction of proximal fragment was noticed due to implant failure. Stretching of wire and breakage of wire were also observed in one animal each in group 2 but that did not affect the fracture fixation. Signs of fracture healing such as appearance of periosteal callus was evident as early as 15th POD in majority of animals in all groups. The complete obliteration of fracture gap by new bone was seen by day 45/60 postoperatively in most of the animals. Osteomyelitis was observed in one animal each in group 1 and group 4.

Neutrophilia and increase total leukocyte count was recorded in all the animals in immediate postoperative period. Serum alkaline phosphatase activity also showed a significant increase ( $P < 0.05$ ) from day 7 onwards and remained high upto day 30. However, there was no significant difference in the TLC, DLC and serum alkaline phosphatase activity among animals of different groups at any interval.

The extension and flexion angles of test elbow joint were reduced markedly on day 15 in animals of group 1, 2 and 4, whereas, in group 3, the reduction in both the angles was minimum. Recovery in these range of motion of elbow joint was also faster in animals of group 3. The rate of recovery of these angles was slowest animals of group 4 in which these values remained significantly ( $P < 0.05$ ) lower than the normal up to day 45 postoperatively. The elbow joint angles at standing, were also reduced on day 15 in all the animals. These

angles remained significantly ( $P < 0.05$ ) lower than the normal in animals of group 2 and 4 upto 45 POD.

Gross observations of the fracture site and the test elbow joint were made after sacrificing the animals on day 60. In majority of animals of group 1, 2 & 3, soft tissue healed completely without any signs of infection. Whereas, in one animal of group 1 and 4 animals of group 4 varying degree of soft tissue infection was noticed. Stainless steel plates and horn plates were encapsulated by a thin and thick layer of fibrous tissue respectively in all the animals of group 1 & 4. Fracture site showed complete union between the fragments in all the animals of group 1, 2 & 3 and in 2 animals of group 4. The amount of new bone was maximum in group 4.

Undecalcified ground sections prepared at the end of observation period were utilized both for photographic enlarged sections study and oxytetracycline labelling study. In all the animals the new bone formation and extent of fracture healing was more in the inner cancellous bone than the outer cortex. Union between fragments was complete in all the animals of group 2 and 3 the fracture healing was more complete in cranial half of fracture line when compared to caudal half. The periosteal new bone formation was excessive in animals of group 4.

Histopathological examination of fracture site in animals of all 4 groups revealed that the fracture healing was faster and more complete on the endosteal side. When compared between different groups, fracture healing was faster in animals of group 3 and slower in group 4. Extensive mononuclear infiltration was also observed in majority of animals of group 4.

# CONCLUSIONS

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Based on the results of this study the following conclusions can be drawn:

1. Fixation of olecranon fracture with the cancellous screw applied in a lag fashion is superior to other techniques as it is easy to perform, causes minimal soft tissue trauma and brings about early uneventful fracture healing.

2. Tension band wiring though provides satisfactory degree of fixation and brings about normal fracture healing, is difficult to perform and associated with more soft tissue trauma.

3. Stainless steel plate can neutralize all disruptive forces at fracture site and can maintain the fixation. More soft tissue trauma and difficulty in its application particularly when proximal fragment in olecranon fracture is smaller, are the limiting factors.

4. The horn plates are not suited for olecranon fractures because of their thickness and minimal availability of soft tissue covering at the site which is invariably associated with wound dehiscence and infection.

## MINI ABSTRACT

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Olecranon fracture repair is difficult due to presence of a *distractive pull by triceps tendon* on proximal fragment. In this study attempts were made to find out the best course of management for repair of such fracture.

Different internal fixation techniques for the management of olecranon fracture were evaluated in 24 mongrel dogs divided in 4 groups. After creating short oblique extra-articular fracture in olecranon, the fracture was fixed with stainless steel plate (group 1), tension band wiring (group 2), cancellous screw (group 3) and horn plate (group 4). The techniques were compared on the basis of intraoperative, clinical, radiological, haematological, biochemical observations, undecalcified ground section studies, gross & histopathological studies and functional status of elbow joint. The technique of cancellous screw application was found to be the easiest and less time consuming. It allowed early return of full weight bearing and faster healing. Tension band wiring was technically more difficult but provided satisfactory fixation. Horn plating was associated with extensive inflammation and lameness that resulted into non/delayed union of fracture in many cases. It was concluded that the cancellous screw application was the most suitable technique for fixation of extra-articular olecranon fracture and that the horn plate is not suited for such fractures.

## लघु सारांश

कफोणि अस्थिभंग का उपचार तिशिरस्का कण्डरा के खिंचाव के कारण कठिन है। प्रस्तुत अध्ययन में इस तरह के अस्थिभंग के उपचार हेतु सर्वोत्तम विधि खोजने का प्रयास किया गया।

कफोणि अस्थिभंग सुधारने हेतु विभिन्न आन्तरिक स्थायीकरण तकनीकों का मूल्यांकन करने के लिये देशी कुत्तों को छः-छः के चार समूहों में बाँटा गया। इन प्रायोगिक कुत्तों के कफोणि अस्थि में तिर्यक बाह्य संधि अस्थिभंग करने के उपरान्त अस्थिभंग को स्टेनलैस स्टील प्लेट (समूह-एक), तनाव पट्टी तार (समूह-दो), सुषिर पेंच (समूह-तीन) तथा सींग प्लेट (समूह-चार) से स्थिर किया गया। अंतः क्रियात्मक, लाक्षणिक, रेडियोलोजिकल, रक्त एवं जैव-रासायनिक प्रेक्षणों, कैल्सियम रहित परिच्छेद, आकारकीय तथा सूक्ष्म आकृति-विकृति अध्ययनों के आधार पर प्रयुक्त विधियों की परस्पर तुलना की गयी। सुषिर-पेंच विधि सबसे सरल तथा कम समय लेने वाली विधि पायी गई एवं इस समूह में टूटे हुये भाग को पूरा भार वहन करने की क्षमता शीघ्र प्राप्त हो गई। इसमें अस्थिभंग सुधार भी जल्दी हुआ। तनाव पट्टी तार विधि तकनीकी रूप से कठिन पायी गयी परन्तु इसके परिणाम संतोषजनक थे। सींग प्लेट विधि से कई प्रायोगिक जानवरों में गम्भीर शोथ एवं लगँडापन उत्पन्न हो गया जिसके कारण घाव या तो नहीं भरा या देरी से भरा। प्रस्तुत अध्ययन से यह निष्कर्ष निकाला गया कि कफोणि अस्थिभंग के उपचार में सुषिर पेंच विधि सर्वाधिक उपयुक्त है तथा ऐसे अस्थिभंग में सींग प्लेट विधि का प्रयोग नहीं किया जाना चाहिये।

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