EFFECT OF METACARPAL OSTEOTOMY AND TRACTION FOR LENGTHENING OF THE FORELIMB IN CALVES

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
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Department of Surgery
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
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DECLARATION

I hereby declare that this thesis entitled "**EFFECT OF METACARPAL OSTEOTOMY AND TRACTION FOR LENGTHENING OF THE FORELIMB IN CALVES**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy,
9 .12.1998

A. KUMARESAN

CERTIFICATE

Certified that this thesis entitled **"EFFECT OF METACARPAL OSTEOTOMY AND TRACTION FOR LENGTHENING OF THE FORELIMB IN CALVES"** is a record of research work done independently by **Sri. A. Kumaresan,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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A. KUMARESAN

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Introduction

INTRODUCTION

In animals, limb deformities are often encountered as congenital contracture of tendons (Greenough *et al.*, 1972), changes in the fetlock, carpal or tarsal joints (Dirksen, 1978), cicatrical contraction of the tendon following accidental injury (Roztocil, 1956) and malunion of fractured bone fragments (Kostlin *et al.*, 1990). The structural deformity leads to functional impairment of the limbs making the animals more prone to severe joint injuries. The productive efficacy of the animal is considerably reduced resulting in enormous economic loss. The economic loss due to limb fractures and associated problems in cattle was estimated to be 33 per cent in a survey of 269 cases (Peitel, 1971).

Osteotomy and traction procedures have been recommended for correction of deformities of limbs. Distraction osteogenesis (Ilizarov, 1969) is the mechanical induction of new bone between bony surfaces that are gradually pulled apart. The biological bridge between the bony surfaces arises from local neovascularization and spans the entire cross-section of the cut surfaces. During distraction, a fibrovascular interface is aligned parallel to the direction of distraction while new bone columns add length, filling the gap. When the biological and mechanical conditions during distraction are ideal, bone is formed by intramembranous ossification.

Ilizarov's external ring fixtors are being used in human patients for the correction of shortened limb (Villa, 1991). In veterinary practice, the same method was tried in dog, horse, cattle and goat (Ilizarov, 1969; Ferretti, 1991; Elkins *et al.*, 1993; Langley-Hobbs *et al.*, 1996 and Wakankar and Chariar, 1997) for the correction of orthopaedic disorders. The use of Ilizarov fixator in large animals is limited due to the mechanical problems of size, weight and the high cost of fixator.

The present study was undertaken with the objectives of:

1. evaluating the effect of metacarpal osteotomy and distraction osteogenesis for lengthening of the limb and

2. to evolve treatment measures that can be adopted for the correction of shortened limb in calves.

Review of Literature

REVIEW OF LITERATURE

Khandekar *et al.* (1963) reported that the correlation coefficient between the live and the dead cannon bone length in lambs, was 0.80. Measurements in the live animal were taken to the nearest 0.1 cm with steel calipers on the fully flexed foreleg from the proximal end of the metacarpus to the lateral condyles at the distal end of the metacarpus.

Ilizarov (1969) designed a circular device with connecting rods to correct angular limb deformities and for lengthening of shortened limb in dogs. After corticotomy, a period of three to seven days was given for local bridging of the gap by fibrous tissue. Distraction was applied afterwards with a distraction rythm at the rate of two to four per day to achieve 1 mm gap per day.

Mohanty *et al.* (1970) evaluated the treatment adopted for the repair of fractures in 26 experimental and 40 clinical cases in cattle and found that after pinning, infection was a frequent complication as much as 25 per cent. It was also observed that fracture treatment and healing had been better in young and light bodyweight animals.

Sittnikow and Paatsama (1970) studied the healing process following transfixation method in artificially created radio-ulnar fracture in dogs. It was observed that fracture healing commenced three days after fracture, at which time osteogenic activity in the endosteum was maximum, but one week later it was more so in the periosteum. The callus in the fracture line, at the later stage, consisted of cartilaginous and fibrous cells. Sixteen weeks later it was ossified and new bone from the periosteum bridged the fracture line almost completely.

Peitel (1971) reported the incidence of limb fractures and the associated economic loss in horses and cattle. He reported the incidence of fracture of metacarpus as 11 per cent in the survey of 269 cattle and economic loss was estimated to be 33 per cent.

Tyagi and Gill (1972) compared the effectiveness of transfixation and bone plating for the treatment of fractures of tibia and large metatarsal bones in two groups of buffalo calves. Transfixation method was found useful in the treatment of oblique fractures, while bone plating method in transverse fractures.

Connell (1974) adopted transfixation pinning for the treatment of fracture of long bones in calves using Kirschner pins, driven through and through obliquely. The protruded portions were welded on to extension rods kept perpendicular on either side. All the animals were ambulatory immediately and healing was uneventful.

Fessler and Amstutz (1974) reported that during fracture healing radiographically a fracture line would be evident even if the periphery of the callus got clinically stabilized. Bony callus developed from vascular periosteum and was evident by fifth day to two weeks. Depending on the blood supply and stability of fracture repair, consolidation of callus took three to ten weeks.

Summer-Smith (1974) compared the fracture healing of radii-ulnae of the poodles with the mongrel dogs. He reported that the callus formation at the fracture site in many mongrels did not bridge the fracture during 2-4 months of observation. However, these fractures were firm and clinically united much earlier than those of the poodles.

Singh and Nigam (1975) reported that fracture gap was visible radiographically even at the end of six weeks of healing, but there were signs of callus formation.

Braden and Brinker (1976) while evaluating bone healing in dogs reported that osteogenic layer between the cortex of the bone and the outer fibrous periosteal layer was responsible for the formation of external callus. The external callus derived its blood supply from periosteum as well as from extraosseous blood supply. The large amount of external fibrous callus stabilized the fracture gap and set the stage for mature callus to develop. Mature callus was mostly trabecular or loosely woven bone.

Sahay and Khan (1976) tried self-polymerising acrylic agents for providing external immobilisation of the Steinmann pins, after achieving percutaneous transfixation of the fractured metacarpal and metatarsal bones in buffalo calves weighing 90-105 kg. The surgical procedures were carried out under brachial plexus block and epidural anaesthesia respectively combined with chloral hydrate narcosis in the treatment of fractures of metacarpal and metatarsal bones in 12 buffalo calves. No incidence of either loosening of the pins or displacement and breakage of acrylic splint was noticed.

Ackerman and Silverman (1978) reported that radiographic evidence of fracture healing became apparent long after clinical healing and hence clinical examination was better for evaluating fracture healing.

Dirksen (1978) reported that the flexion and hyperextension malformations of the front and rear limbs in calves were frequently due to congenital changes in fetlock, carpal or tarsal joints.

Hamilton and Tulleners (1980) treated fracture of tibia in three calves by transfixation pinning. Alignment was excellent and the animal was bearing weight on the limb.

Sharma *et al.* (1980) studied the effect of time of immobilization on fracture healing in induced fracture of metatarsus in buffaloes and concluded that the best time for immobilisation of fractures in large animals was around the third day after fracture.

Egger (1983) evaluated the use of external skeletal fixators in human and small animal orthopedics for fracture stabilization and opined that the external skeletal fixator was well suited for management of comminuted, and open or infected fractures.

Singh and Nigam (1983) studied the normal venous channels and also vascular changes in relation to healing of metatarsal fractures in buffalo calves. Fractures markedly interfered with intraosseous venous flow and resulted in delayed drainage and stasis of contrast medium. The cross-over medullary vascular connections through the fracture was observed by fourth week, but the complete medullary vascular connections were not observed even upto tenth week. In cases of delayed healing the flow of contrast medium across the fracture gap was not observed. A positive correlation was noticed between the establishment of medullary vascular connection and the rate of fracture healing.

Singh *et al.* (1984) reviewed the postoperative complications in 270 cases of fractures in large animals and found that malalignment and infection were the most common postoperative complications after external and internal immobilisation of fractures. Complications after transfixation were malunion, delayed union, infection at fracture site and at pinpoint and excessive callus formation. The reported complications were 38.4 per cent.

Chambers and Betts (1985) successfully employed fracture distractor for immobilisation of the long bone fractures in dog. Bolts were placed across the bone above or below the fracture and connected to a threaded rod allowing controlled lengthening of the limb.

Brinker *et al.* (1990) achieved stiffness of the external fixator by using three or four pins per fragment. Clinically, it appeared that one of the major advantages of using more than two pins per fragment was better distribution of the forces. It was seen that the bending and loosening of pins were less commonly encountered when three to four pins were used per fragment.

Kostlin *et al.* (1990) carried out studies on fractures of metacarpal and metatarsal bones in cattle and reported that the complications during fracture repair encountered were shortening of limb, bending of the affected limb, dislocation of the fragments within the cast and osteomyelitis.

Aronson (1991) suggested that the rate of distraction, should remain within a range of one-half to two millimeters per day averaging one millimeter per day. The average recommended latency was four to seven days (Latency is the time period between the operation and the initiation of distraction). He studied the histology of distraction osteogenesis. A fibrovascular network bridged the distraction gap by day 7 (postoperative day 14) of distraction and there was also no evidence of new mineralization. By day 14 of distraction (postoperative day 21), new bone was first seen forming at the two cut surfaces of the corticotomy. The new bone arose from the entire cross-section including spongiosa, cortex and periosteum. At day 21 of distraction (postoperative day 28), the new bone had differentiated into micro-columns with maximum diameters of 200 microns. The central region of the osteogenic area remained as a fibrous interzone, containing trace amounts of calcium and no crystallized hydroxyapatite. The fibrous interzone persisted throughout the period of distraction, averaging three to four millimeters in length. By postoperative day 77, the bone columns bridged across the fibrous interzone and the osteogenic area had remodeled, radiographically demonstrating early cortex formation. By postoperative day 119 the osteogenic area contained lamellar bone with Haversian systems and hematopoietic marrow.

Ferretti (1991) had treated open and comminuted fractures, septic and aseptic pseudarthroses, congenital and traumatic dislocations, angular deformities, shortening, joint stiffness and fracture malunions by using Ilizarov technique in dogs and cats. The technique was also employed in the treatment of multiple fracture of right metacarpus in a steer, fracture of the left radius in a goat and anterior flexion of the fetlock at the metacarpophalangeal joint in a horse.

Paley (1991) reviewed the problems and complications of limb lengthening in human patients. The complications encountered were muscle contractures, joint luxation, axial deviation, neurologic injury, vascular injury, premature consolidation, delayed consolidation, wire-site problems, wire skin motion, refracture, joint stiffness and pain. Axial deviation occurred due to imbalance between muscle forces on different sides of the bone. The direction of deviation depended upon the bone involved and the level of the osteotomy. It was opined that the occurrence of axial deviation in the proximal tibia could be prevented by placing the wires 5° to 10° inclined to the opposite direction of the expected deviation. Severe pain was evinced when the bone was subjected for longer lengthening and also when the daily distraction rate was increased.

St-Jean *et al.* (1991) reviewed the transfixation pinning and casting of tibial fractures in five calves. Radiographic and clinical evidence of stability of fracture was observed in 5 to 10 weeks, and the limb returned to normal function after 3 to 12 months.

Villa (1991) recommended that in limb lengthening, distraction at the rate of one millimeter per day can be achieved without interruption of the function of the limb.

Elkins *et al.* (1993) successfully employed a modified Ilizarov external ring for correcting carpus valgus in a six month old boxer, where osteotomy was performed with intact periosteum.

Forell and Schwanz (1993) treated carpal angular deformity by corrective osteotomy with external skeletal fixation in 18 mature dogs. The improvement in limb function was observed in 67 per cent of the cases. Better cosmetic results were obtained in dogs where the postoperative limb position was within a range of neutral to 4° valgus. Pin tract infection and osteomyelitis were the common postoperative complications.

Van Vechten and Vasseur (1993) corrected the mild valgus deformity which was due to premature closure of distal radial physis by removing 1 cm length of bone of the mid diaphysis. The limb was supported with a splint for three weeks after surgery. Radiograph taken three weeks after surgery, revealed caudolateral deviation of the proximal aspect of the distal radial fragment and evidence of disuse osteoporosis throughout the radius. Radiograph taken 13 months after surgery, revealed progressive remodelling of the callus associated with radial ostectomy.

Mc Clure *et al*. (1994) carried out *in vitro* comparison of the effect of parallel and divergent transfixation pins on breaking strength of third metacarpal bones of equine. It was found that the divergent pins were significantly stronger than the parallel pins.

Edinger *et al*. (1995) successfully corrected 45° angular limb deviation in a five week old calf by performing periosteal stripping and wedge osteotomy. The deformity was caused by the malaligned healing of a fracture of the left metacarpus after birth trauma. The deviation improved to 25°

after being treated with a semicircular lateral periosteotomy above the distal physis of the radius. A complete correction of the deviation was achieved with wedge osteotomy, five months after the first treatment. A 20° wedge shaped bone was removed and the metacarpus was stabilized with a seven-hole dynamic compression plate, which was removed 12 weeks later.

Latte (1995) treated fractures, fracture complications, growth abnormalities and other bone structure related disorders in 64 dogs with bodyweight ranging from 1.7 kg to 70 kg. Among these, 29 dogs were subjected to bone lengthening from 9 to 60 mm. Consolidation occurred in 87 per cent of cases in a mean time of 54 days. Sixty four per cent of the results were considered good or very good, the failure was 12 per cent, complications were 39 per cent and the re-operations were 32 per cent. He opined that partial tenotomy of the superficial flexor would be beneficial in bone lengthening procedures.

Langley-Hobbs *et al.* (1996) employed Ilizarov apparatus for lengthening of shortened forelimb due to the synostosis which occurred after the healing of radius and ulna in a nine week old Labrador. Carpal hyperflexion was the complication observed and was managed by bandaging in forced extension.

Mc Clure *et al.* (1996) compared the *in vitro* axial stability provided by four methods of attaching transfixation pins into a fibreglass cast cylinder. Methods of attachment included simple incorporation of the pins into the cast, placement of a washer and nut on the pin and incorporation into the cast, extension of pins beyond the cast and attachment to a steel halo, and washers within the cast and attachment to a steel halo. There was no significant difference among four methods of attachment.

Pattanaik *et al.* (1996) used fabricated uniaxially dynamic full pin transfixation device for the repair of metatarsal and tibial fractures in hill bulls and was found successful.

Chawla *et al.* (1997) evaluated osteomedullographic findings in fracture healing. Intraosseous venous flow was seen reconstituted earlier in animals, where rigid immobilization was achieved. The positive osteomedullographic signs observed in normally healing fractures were (i) vein crossing the fracture gap, (ii) proximal sinusoidal network, (iii) periosteal veins of proximal fragment, (iv) ascending branch of main efferent vein and (v) vein crossing the callus. Presence of any one of these signs was considered as an indication of re-establishment of intraosseous venous circulation through the fracture. Complete reconstitution of venous connections was observed within a period of 8 to 12 weeks.

Wakankar and Chariar (1997) reported the usefulness of Ilizarov technique for the treatment of various orthopaedic disorders in small and large animals. The technique was helpful to create fibrous arthrodeses in septic arthritis and open joint at the carpus in one dog and a similar lesion at the fetlock in a bovine. The technique yielded itself well in treating old compound and infected fractures with osteomyelitis in the tibia of a canine and in the metatarsus of a bovine. Stability and strength of the fixator permitted early weight bearing and ambulation in large as well as small animals. The fixation consisted of transosseous wires at sites remote from the infected site of the lesion. These two factors played an important role in successful use of the fixator.

Materials and Methods

MATERIALS AND METHODS

The experimental study was conducted in 12 apparently healthy crossbred bull calves aged six to twelve months and weighing 60 to 120 kg. They were kept under observation for a period of 10 days prior to the experiment, under identical conditions of feeding and management.

The animals were randomly divided into two groups viz. Group I and II consisting of six animals each and were numbered serially as:

I/1, I/2, I/3, I/4, I/5, I/6 and
II/1, II/2, II/3, II/4, II/5, II/6

The experimental procedures in each group were

Group I

Transverse osteotomy was performed at the mid-shaft region of the left metacarpal bone. The bone fragments were immobilized with the help of locally fabricated full pin transverse fixation device. From the sixth day onwards the bone fragments were retracted in opposite directions at the rate of 1 mm gap/day for 10 days.

Group II

Transverse osteotomy was performed at the mid-shaft region of the left metacarpal bone. The limb was immobilized as in Group I. On the sixth day, partial tenotomy of the flexor tendons was performed and the bone fragments were retracted as in group I at the rate of 1 mm gap/day for 10 days.

Fabrication of full pin transverse fixator

The device comprised of four transverse pins, external connecting bars and stabilizing rods. Transverse pins and stabilizing rods were prepared from Steinmann pins of 3 mm diameter. Transverse pins were 10 cm in length with both ends threaded and one end sharpened. Stabilising rods were 12.5 cm long with both the ends threaded. The external connecting bar comprised of proximal and distal stainless steel pipes of 6-8 mm diameter, in which stainless steel plate was welded in front and two `L' shaped stainless steel pieces were welded on back. In addition to this, a 4.5 mm diameter and 2.5 cm long threaded steinmann pin having 10 threads/cm was connected to the distal aspect of the proximal stainless steel pipe. The free portion of the threaded rod was inserted into the distal stainless steel pipe. All the pins and stabilizing rods were connected to the external connecting bars by using nuts. Traction was possible by rotating the nut which was placed in between the proximal and distal connecting bars and one full turn of the nut was equal to 1 mm (Fig.1 and 2).

Preoperative preparation

The animals were prepared by withholding feed for 24 hours and water for 12 hours prior to surgery.

The left forelimb extending from the elbow joint to the hoof was thoroughly scrubbed with cetrimide lotion[1]. The entire metacarpal region was shaved, washed with soap and water, cleaned and mopped dry. The area was painted with Tr. iodine (Fig.3).

The animals were controlled on right lateral recumbency and the limbs were secured leaving the left forelimb free. The whole body of the animal was suitably draped.

Anaesthesia

The animals were sedated with IM administration of xylazine[2] at the rate of 0.2 mg/kg bodyweight. Regional analgesia of the limb was achieved by brachial plexus block using 10-15 ml of two per cent solution of lignocaine

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1. Suphalon - Southern Union Pharmaceuticals, Thrissur
2. Xylocad 2% solution - Cadila Veterinary, Ahamedabad

hydrochloride[3]. Incremental doses of xylazine and lignocaine hydrochloride were repeated as per requirement.

Brachial plexus block

Under aseptic precaution, a 16 cm long, 18 gauge hypodermic needle was inserted in level with and 6-8 cm anterior to the acromian process of the scapula. The needle was directed posteriorly and horizontally, medial to the scapula until the tip was in level with lateral aspect of the first rib (Fig.4). Brachial plexus blockade was achieved by infiltrating 10-15 ml of two per cent solution of lignocaine hydrochloride in the form of a band (6-8 cm) at the site and along the rib downward. Care was taken to avoid injection into the brachial vessels.

Technique

Group I

A skin incision, 10 cm long was made over the mid shaft region on the antero-lateral aspect of the metacarpal bone. The subcutaneous fascia and periosteum were incised and periosteum was separated. Using a gigli wire saw transverse

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3. Xylocaine 2% solution - Astra IDC Ltd., Bangalore

osteotomy was performed (Fig.5). The fractured ends were brought into apposition and immobilized with the help of a locally fabricated full pin transverse fixation device. The periosteum was apposed by continuous lock stitch using 1/0 braided silk and the subcutaneous fascia and the skin by vertical mattress sutures using monofilament nylon. Tr. benzoin seal was applied over the suture line and the area was bandaged. From sixth day onwards, the bone fragments were retracted in opposite direction at the rate of 1 mm gap/day for 10 days. Skin sutures were removed on the 10th postoperative day. The immobilization with the fabricated full pin transverse fixation device was maintained for 45 days.

Group II

Transverse osteotomy and immobilization with fabricated full pin transverse fixation device were done as in Group I. On the sixth day, partial tenotomy of flexor tendons (Accordian method) was carried out (Butler, 1974). The bone fragments were retracted in opposite directions at the rate of 1 mm gap/day for 10 days after tenotomy. The immobilization was maintained with the locally fabricated full pin transverse fixation device for 45 days.

Postoperative care

Streptopenicillin[4] (1.25 g) was administered IM for 10 consecutive days starting from the day of osteotomy. Analgin[5] (2.5 g) was also administered IM for five consecutive days to all animals. Suture line and pin holes were cleaned with 70 per cent ethyl alcohol and dressed with betadine ointment[6] daily from sixth day to 15th day and bandage was applied in a figure of eight manner, avoiding the connecting bars. Thereafter the dressing and bandaging were done at weekly intervals during the period of observation. Skin sutures of osteotomy and tenotomy wounds were removed on the 10th and 15th postoperative day respectively.

All the animals were kept under observation for a period upto 45 days and thereafter they were sacrificed and the metacarpal bones were harvested.

Main items of observation

a. Physiological observations

Respiration rate, pulse rate, rectal temperature and colour of mucous membrane were recorded before surgery and thereafter daily for 10 consecutive days.

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4. Dicrysticin-S - Sarabhai Chemicals, Baroda
5. Novalgin Vet. - Hoechst Roussel Vet. Pvt. Ltd., Mumbai
6. Betadine Ointment - Win-Medicare Ltd., New Delhi

b. Haematological observations

Blood samples were collected before surgery, at 24 h, on 7th, 14th, 28th and 42nd day after surgery. It was used for estimation of total and differential leukocyte counts, total erythrocyte count, haemoglobin concentration (Schalm, 1975) and packed cell volume (Benjamin, 1978).

c. Clinical observations

Clinical symptoms, efficacy of immobilisation and functional status of the limb were recorded.

d. Radiographic observations

Radiographs of the metacarpal region were taken (anteroposterior view) immediately after surgery and on the 5th, 15th, 30th and 45th postoperative days. Radiographs of the harvested metacarpal bones were also taken and compared with the opposite normal metacarpal bone.

e. Gross and histological examination of the harvested bones

All the animals were sacrificed after 45th day and the metacarpal bones were harvested. The gross and histological examinations of the harvested bones were carried out.

Histological technique

Pieces of bone along with the callus in sizes of 5 mm thickness were cut from the fracture site, fixed, decalcified, dehydrated, cleared and embedded in paraffin. Sections 5-10 μm thickness were prepared and stained using haematoxylin and eosin stains (Drury *et al.*, 1967).

f. **Physical measurements of the limb and the harvested bones**

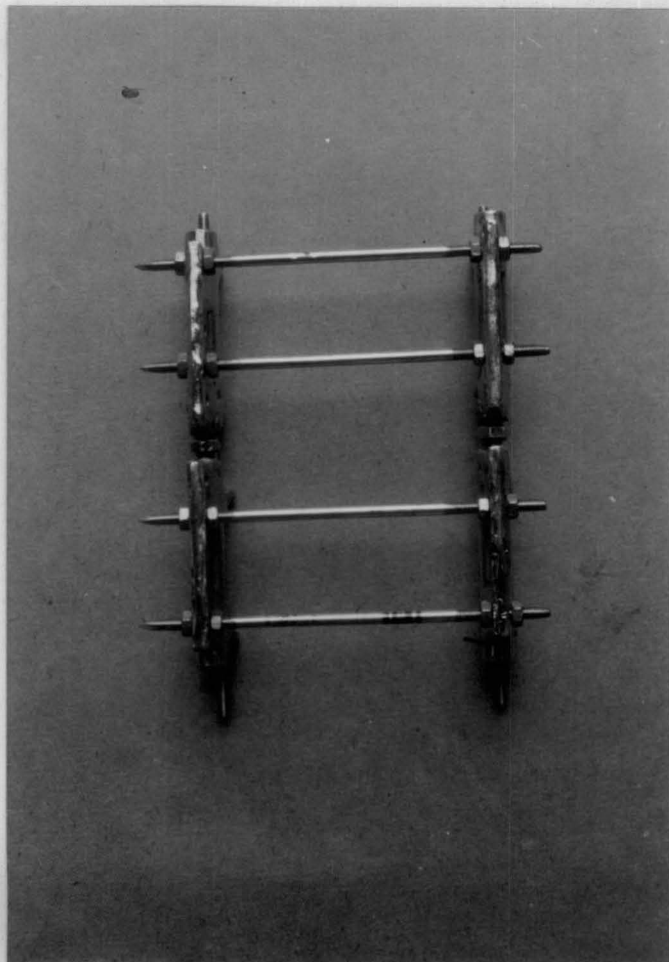
The length of metacarpus (in cm) (Khandekar *et al.*, 1963) and the length of the limb from the point of shoulder to the coronet were measured before operation and on the 45th postoperative day. The length of the harvested metacarpal bones (both the operated and opposite normal) was also recorded.

The data were analysed by students `t' test (Snedecor and Cochran, 1967).

Fig.1. Full pin transverse fixator

Fig.2. Different components of full pin transverse fixator assembly

a. Transverse pins
b. Stabilizing rods
c. Connecting bars



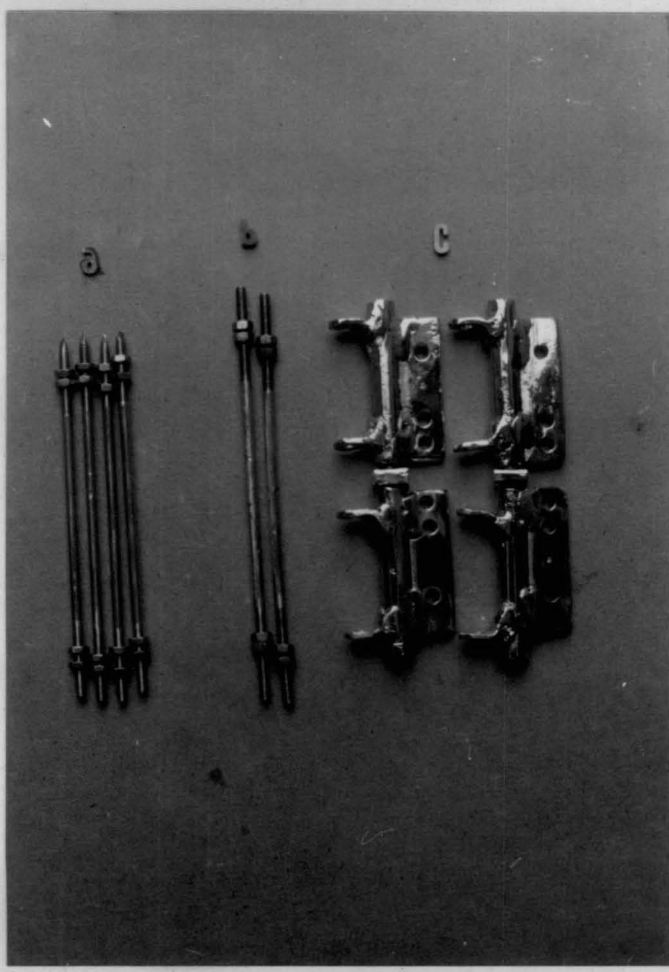
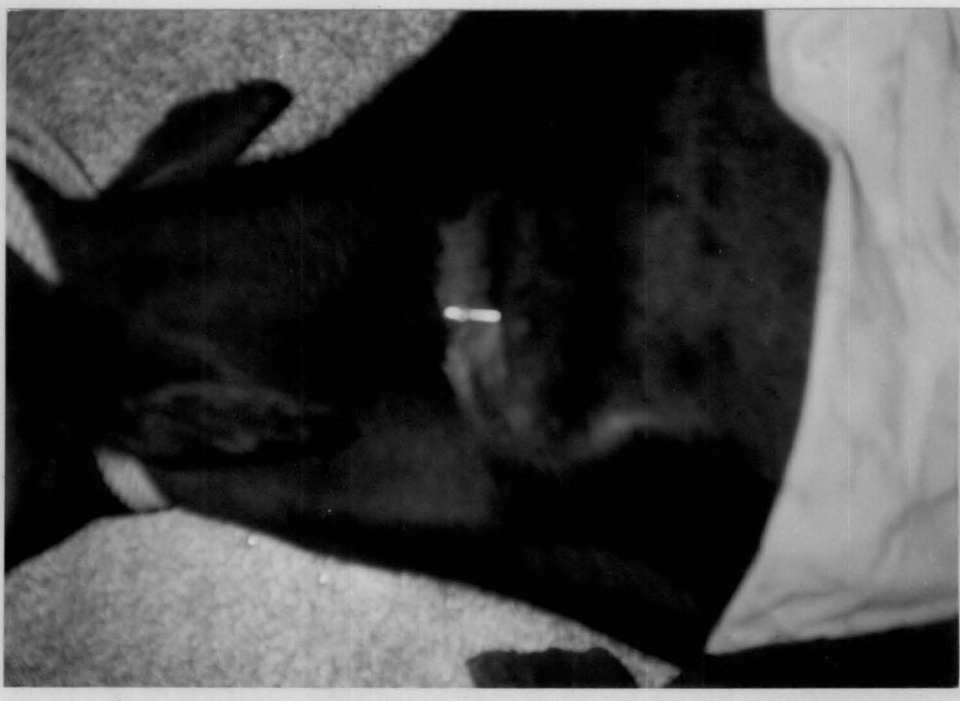

a
b
c

Fig.3. **Animal showing the site of operation the adhesive tape indicates the line of incision**

Fig.4. **The needle in position for administration of anaesthetic for brachial plexus block**

Fig.5. **Photograph showing the osteotomy of the metacarpal bone using gigli wire saw**



Results

RESULTS

The experimental study was conducted in 12 apparently healthy crossbred bull calves. They were randomly divided into two groups viz., Group I and Group II. In group I, the animals were numbered serially from I/1 to I/6 and in group II, the animals were numbered serially from II/1 to II/6.

GROUP I

The average bodyweight of the animals was 65.33 ± 2.17 kg. All the animals were sedated by administering two per cent xylazine at the rate of 0.2 mg/kg bodyweight intramuscularly. Sedation was achieved within 7.50 ± 0.62 minutes and the effect persisted for 55.33 ± 4.42 minutes. Half the dose was repeated when animal showed signs of recovery (Table 1). Regional analgesia of the operated limb was produced by brachial plexus block using two per cent solution of lignocaine hydrochloride 10-15 ml and the effect persisted for 38.83 ± 15.85 minutes (Table 2).

Physiological observations (Table 3)

A slight increase in rectal temperature was noticed in all the animals upto 10th postoperative day and thereafter it gradually reduced to normal limit. An increase in pulse rate was observed throughout the period of observation and the increase was significant on second day. Respiration rate was seen increased initially but was within normal limits throughout the period of observation.

Haematological observations (Table 4)

The total erythrocyte count was seen increased by 24 h after the operation, but the increase was not significant. Thereafter it reduced to normal limits. The total leukocyte count was seen increased by 24 h and the increase persisted throughout the period of observation. By the 7th day the increase was maximum, but was not significant.

The haemoglobin concentration was seen reduced throughout the period of observation. The packed cell volume was seen increased by 24 h following the operation and thereafter the increase persisted throughout the period of observation but the values were not significant.

There was an increase in neutrophil count with relative decrease in lymphocyte count upto the 7th postoperative day and thereafter the counts returned to the normal limits. The eosinophil count was seen decreased throughout the period of observation, but the variations in monocyte and basophil counts were marginal.

Clinical observations (Table 5)

All the animals were able to get up unassisted and were able to walk with limping within 24 hours after surgery. They were able to bear the weight on the limb within 24 hours to three days (Fig.6).

First week

All the animals favoured the fractured limb with the toe pointing and the limb was oedematous from knee downwards. Nodding of head and limping with occasional stumbling were observed while walking. Angulation of limb was noticed in three animals (I/1, I/4, I/6). Signs of Pain were observed in two animals (I/2, I/5). The external fixators were intact in all the animals.

Second week

All the animals favoured the fractured limb with toe pointing. Nodding of head and limping was observed in all animals. Stumbling persisted in two animals (I/1, I/6). Angulation of the limb was observed in three animals (I/1, I/4, 1/6). Oozing of purulent discharge was noticed from the pin tracts and fracture site in one animal (I/2). Oedema of the operated limb was observed in all the animals but was marked in three animals (I/1, I/5, I/6). The external fixator became loose in one animal (I/2).

Third week

Favouring of the limb while standing persisted in three animals (I/2, I/5, I/6). Nodding of head and limping were observed in all animals while walking. Angulation of the fractured limb was reduced in two animals (I/1 and I/4). Oozing of purulent discharge from the pin tracts and fracture site persisted in one animal (I/2). The amount of oedema was reduced in two animals (I/3, I/4).

Fourth week

Animals I/2, I/5 and I/6 favoured the fractured limb with toe touching the ground. Nodding of head and limping, persisted in all the animals. In one animal (I/6), occasional stumbling was observed. The angulation of fractured limb (I/1, I/4) was almost reduced to normal. Oozing of discharge from pin tracts and fracture site had stopped completely (I/2, I/5). The oedema on limb was observed in two animals (I/2, I/5). In two animals (I/5, I/6), the external fixator was found to be loose.

Fifth week

Favouring of the fractured limb with toe pointing was observed in animals I/2, I/5 and I/6. Nodding of head and limping were observed in all animals except I/3. The fixator was loose in two more animals (I/1, I/4). Oedema was seen in animals I/2, I/5. Angulation persisted in animal I/6 (Fig.7).

Sixth week

Animals (I/2, I/5) favoured the fractured limb markedly. Nodding of head and limping were observed in one animal (I/2). Oedema persisted in animals I/2 and I/5. In other animals the functional status of the limb was maintained (Fig.8). The fixator was found loose in two animals (I/1, I/4).

Radiographic observations

First day

Radiographs taken immediately after the operation revealed perfect alignment of fragments in two animals (I/1, I/3) (Fig.9) and partial displacement of the fragments in others (Fig.10).

Fifth day

Radiographs revealed perfect alignment of fragments in two animals (I/1, I/3). The displacement of fragments persisted in others.

Fifteenth day

The fragments were seen retracted in all the animals (Fig.11). Radiodense areas were seen on the edges of both the fractured fragments and periosteal callus was seen on either side of the pins in animals (I/1, I/3), but was less evident in other animals.

Thirtieth day

Radiodensity of bony proliferation from the fractured fragments could be appreciated (Fig.12) and was less evident in two animals (I/2, I/6). Prominent radiolucency was seen at the centre of the gap in all animals.

Fortyfifth day

Bridging of the gap between the fragments by radiodense callus was evident in all the animals except in animals I/2 and I/6 where the callus was radiolucent. The callus was not completely ossified (Fig.13). Extensive periosteal callus was visualized in all animals but was more evident in animals (I/1, I/3, I/4).

Gross observation of harvested bone

The callus was well developed and firm. The fragments were immobile in all the animals except in I/2 and I/6 where there was mobility of the fragments but, signs of callus formation was noticed (Fig.14 and 15).

Radiograph of the harvested bone

Displacement of the fragments were seen on the radiograph of the harvested bone in all the animals. The fragments were highly displaced in animal I/6. Radiodense areas were seen in the fracture gap and the callus was not united at the centre. Extensive periosteal proliferation was noticed around the pintract (Fig.16). Radiolucent osteolytic areas at the cut ends of each fragments were seen in animal I/2.

Radiographic measurement of length was taken from the most proximal and most distal articulations. It was 16.9 ± 0.18 in the right normal metacarpal bone and was 17.73 ± 0.26 in the operated left metacarpal bone on 45th postoperative day (Table 6).

Histological observations

There was well developed subperiosteal, external callus. Internal callus was seen in the interfragmentary gap. The callus showed zones of newly formed fibrous tissue which were united at the centre of the interfragmentary gap. The proliferation of fibrous tissue with formation of osseous trabeculae was also noticed. New trabecular bone extended from the cut surface of the cortical bone into the callus. The trabeculae were irregular and numerous with abundant branching, indicating that the callus was still cancellous in nature. In all animals, except in two (I/1, I/6), extensive formation of new trabecular bone and connective tissue proliferation were noticed within the callus (Fig.17). Well developed internal callus was noticed in the medullary cavity.

Vascularization of callus with infiltration of lymphocytes were seen and there was poorly organised osteoids, with abundant osteons, woven bones and cartilage (Fig.18).

Physical measurements of the limb and the harvested bones

The measurement of length of the operated limb (in cm), taken from shoulder joint to coronet and it was 55.97 ± 1.32 before operation and 57.10 ± 1.28 on the 45th postoperative day. The measurement taken from knee joint to fetlock joint was 17.43 ± 0.13 before operation and 18.42 ± 0.15 on the 45th postoperative day. The measurement of circumference at the fracture site was 10.35 ± 0.14 before operation and 11.57 ± 0.27 on the 45th postoperative day. The length of the harvested right normal metacarpal bone was 17.05 ± 0.15 and it was 17.90 ± 0.20 in the operated left metacarpal bone (Table 6).

Table 1. Induction time, duration of sedation and period of recovery (in min) following administration of xylazine in calves (Group I)

n=6

Animal No.	Body weight (kg)	Quantity of xylazine used (mg)		Induction time (min) after Ist Admn.	Duration of sedation (min)			Recovery period
		Ist admn.	IInd admn.		After Ist admn.	After IInd admn.	Total	
I/1	68	13.6	10.0	8	64	54	118	60
I/2	60	12.0	5.0	10	67	43	110	45
I/3	60	12.0	5.0	8	52	53	105	48
I/4	62	12.4	5.0	6	42	70	112	56
I/5	70	14.0	10.0	6	44	56	100	42
I/6	72	14.4	5.0	7	63	45	108	60
	65.33± 2.17	13.07± 0.43	6.67± 1.05	7.50± 0.62	55.33± 4.42	53.50± 3.92	108.83± 2.51	51.83± 3.21

Table 2. Time of induction and duration of regional analgesia (in min.) following brachial plexus block with lignocaine hydrochloride solution in calves (Group I)

n=6

Animal No.	Body weight (kg)	Quantity of lignocaine hydrochloride used (ml)			Total quantity used (ml)	Time of induction after Ist administration	Duration of regional analgesia (min)			Total duration of analgesis
		Ist administration	IInd administration	IIIrd administration			After Ist administration	After IInd administration	After IIIrd administration	
I/1	68	10	10	5	25	5	45	38	30	113
I/2	60	10	10	10	30	5	41	35	28	104
I/3	60	10	10	5	25	7	37	30	33	100
I/4	62	10	10	5	25	5	32	35	30	97
I/5	70	15	5	5	25	4	38	25	28	91
I/6	72	15	10	5	30	5	40	32	22	94
	65.33± 2.17	11.67± 1.05	9.17± 0.83	5.83± 0.83	26.67± 1.05	5.17± 0.40	38.83± 15.85	32.50± 1.87	28.50± 1.50	99.83± 3.22

Table 3. Rectal temperature, pulse rate and respiration rate before surgery and on different postoperative periods in calves (Group I) (Mean±SE)

n=6

Parameters	Postoperative intervals (day)													
	0	1	2	3	4	5	6	7	8	9	10	15	30	45
Temperature (°C)	38.25± 0.15	38.92± 0.15	39.45± 0.28	39.38± 0.15	39.02± 0.14	38.83± 0.14	39.00± 0.14	39.05± 0.14	39.00± 0.16	39.02± 0.16	38.75± 0.16	38.95± 0.16	38.73± 0.13	38.68± 0.08
Pulse rate (per minute)	73.50± 9.76	98.00± 9.34	102.17±* 9.01	88.00± 4.68	97.67± 7.56	86.33± 5.40	93.00± 7.67	94.67± 10.24	95.67± 9.83	92.33± 9.13	80.33± 5.33	78.68± 3.48	72.00± 5.66	71.60± 4.78
Respiration rate (per minute)	22.50± 1.77	27.00± 2.24	28.83± 1.42	28.67± 0.84	26.33± 1.67	24.33± 1.58	25.33± 1.91	26.00± 1.13	24.83± 1.42	26.33± 2.51	23.50± 1.54	24.28± 1.82	24.17± 1.33	23.80± 1.33

* Significant at 5 per cent level

Table 4. Haemogram before surgery and on different postoperative periods in calves (Group I) (Mean±SE)

n=6

Parameters	Postoperative intervals					
	Before operation	After 24 h	7th day	14th day	28th day	42nd day
Total erythrocyte count ($10^6/mm^3$)	7.27±0.46	7.86±0.44	7.30±0.20	7.06±0.51	7.22±0.36	7.22±0.61
Total leukocyte count ($10^3/mm^3$)	9.23±0.64	9.52±0.65	9.93±0.81	9.75±0.74	9.56±0.73	9.80±0.67
Haemoglobin concentration (g/dl)	9.98±0.43	9.48±0.44	9.13±0.33	8.28±0.62	8.88±0.27	8.72±0.25
Packed cell volume (%)	29.60±2.33	35.50±2.33	33.83±2.60	30.86±2.34	33.17±1.49	30.17±1.94
Differential count						
Neutrophils (%)	30.00±1.69	33.67±2.04	34.00±3.77	28.26±3.65	28.33±2.64	29.83±2.43
Lymphocytes (%)	66.67±2.33	64.17±1.72	63.50±3.76	69.50±4.37	70.33±2.55	67.17±1.91
Monocytes (%)	1.50±0.76	1.33±0.42	1.33±0.33	1.67±0.72	1.00±0.12	1.40±0.37
Eosinophils (%)	2.17±0.60	0.83±0.48	1.17±0.31	0.67±0.33	0.50±0.22	1.00±0.41
Basophils (%)	0.00	0.00	0.00	0.17±0.17	0.17±0.17	0.00

Table 5. Observations on clinical symptoms and complications following transfixation at different postoperative intervals (in weeks) in calves (Group I)

Animal No.	Favouring the fractured limb (persisted upto)	Pain (persisted upto)	Stumbling (persisted upto)	Nodding of head and limping (persisted upto)	Oedema (persisted upto)	Angulation of limb (persisted upto)	Pin bending	Pin/ fixator loosening	Pin tract infection	Fracture site infection	Remarks
I/1	2	2	2	5	3	4	-	5	-	-	-
I/2	6	3	-	6	6	-	-	2	2-3	2-3	-
I/3	2	2	-	4	2	-	-	-	-	-	-
I/4	2	2	-	5	2	4	-	5	-	-	-
I/5	6	3	-	5	6	-	-	4	-	-	-
I/6	5	4	4	5	3	5	-	4	-	-	-

Table 6. Measurements of the operated limbs, before operation and on 45th postoperative day and the harvested operated and opposite normal metacarpal bones (Group I)

Animal No.	Body weight (kg)	Measurement of the limb (in cm)						Measurement of the metacarpal bone (in cm)			
		Before operation			On the 45th postoperative day			On 45th postoperative day			
								Harvested bone		Radiographic measurement	
		Shoulder to coronet	Knee joint to fetlock joint	Circumference at midshaft region of metacarpus	Shoulder to coronet	Knee joint to fetlock joint	Circumference at midshaft region of metacarpus	Rt limb (Normal)	Lt limb (Operated)	Rt limb (Normal)	Lt limb (Operated)
I/1	68	58.00	17.4	10.5	58.9	18.8	11.5	17.1	18.1	17.2	18.2
I/2	60	59.00	17.3	10.8	60.3	18.0	12.5	16.6	17.2	16.5	17.0
I/3	60	55.00	17.3	10.0	55.8	18.2	10.6	16.9	17.7	16.3	17.0
I/4	62	50.00	17.1	10.2	51.5	18.1	11.6	16.8	17.6	16.9	17.8
I/5	70	56.30	17.5	10.0	57.5	18.6	11.2	17.3	18.2	17.0	17.8
I/6	72	57.50	18.0	10.6	58.6	18.8	12.0	17.6	18.6	17.5	18.6
	65.33± 2.17	55.97± 1.32	17.43± 0.13	10.35± 0.14	57.10± 1.28	18.42± 0.15	11.57± 0.27	17.05± 0.15	17.90± 0.20	16.90± 0.18	17.73± 0.26

Fig.6. Animal showing complete weight bearing on the limb on the day after the surgery

Fig.7. Animal showing angulation of the fractured limb (35th postoperative day group I)

Fig.8. **Animal showing normal gait on 45th postoperative day (Group I)**

Fig.9. **Skiagram of the left metacarpus, immediately after application of the fixator showing the fragments in apposition (Group I)**

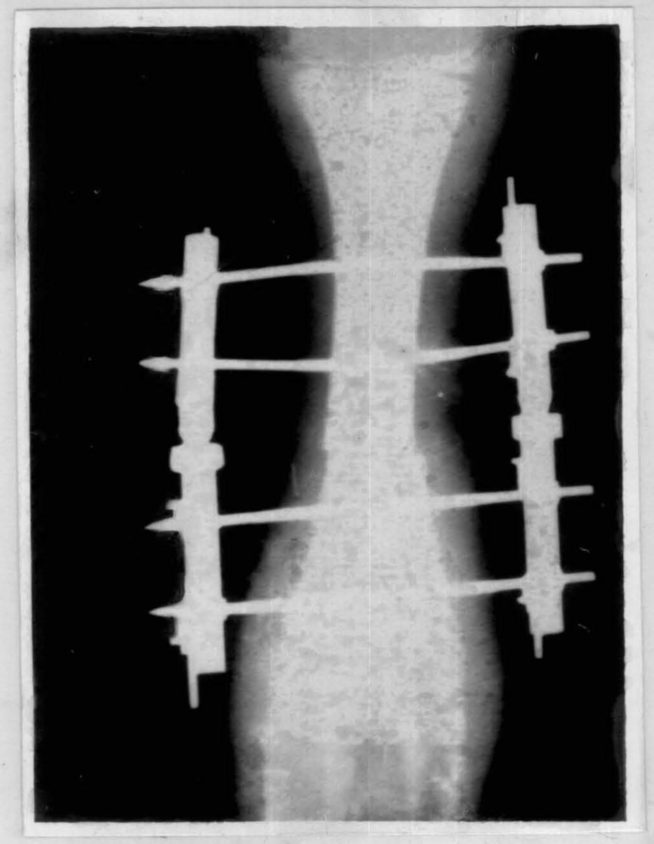
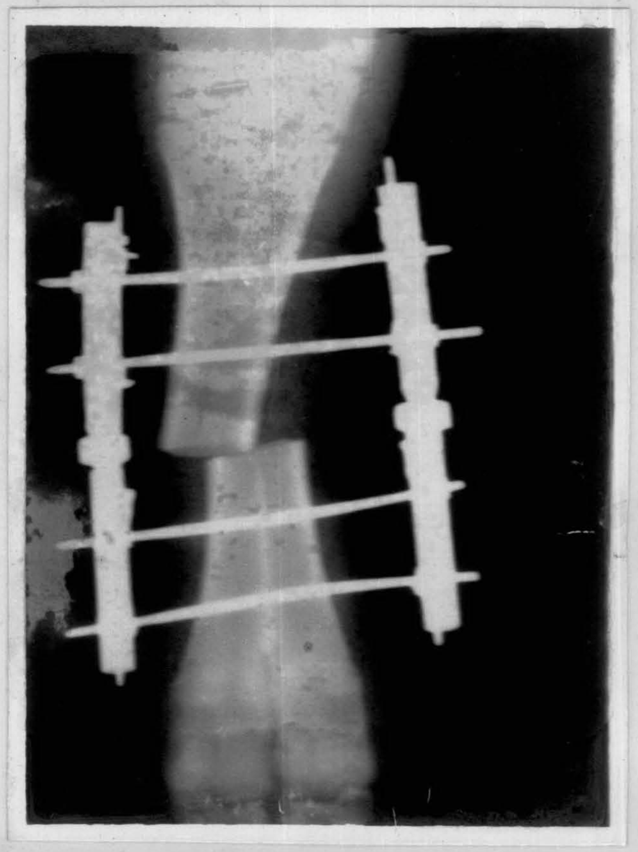


Fig.10. Skiagram of the left metacarpus, immediately after application of the fixator showing partial displacement of the fragments (Group I)

Fig.11. Skiagram of the left metacarpus, immediately after termination of the traction showing the fragments retracted (15 the postoperative day in Group I)



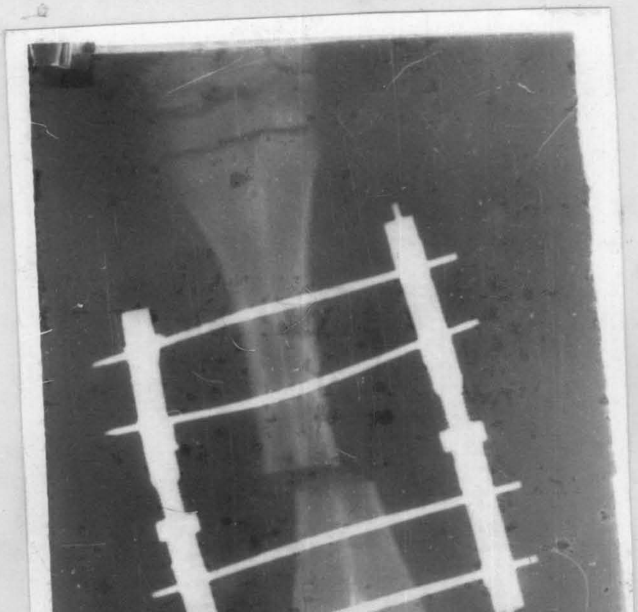
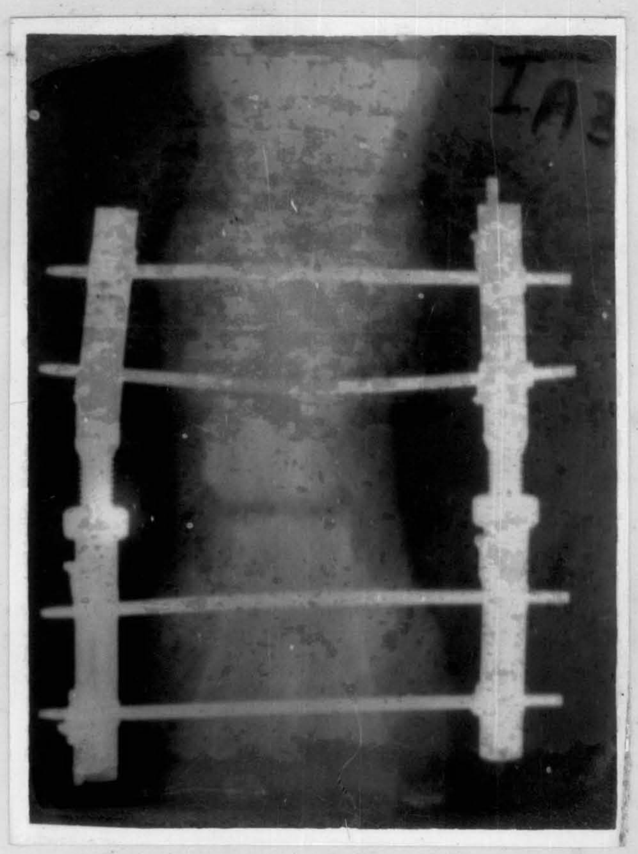

15

Fig.12. **Skiagram of the left metacarpus, 15 days after termination of the traction showing radiodense areas from the cut ends of both the fragments with extensive periosteal callus (Group I)**

Fig.13. **Skiagram of the left metacarpus, 30 days after termination of the traction showing ossified callus near the cut ends with central radiolucent gap (group I)**


IA3

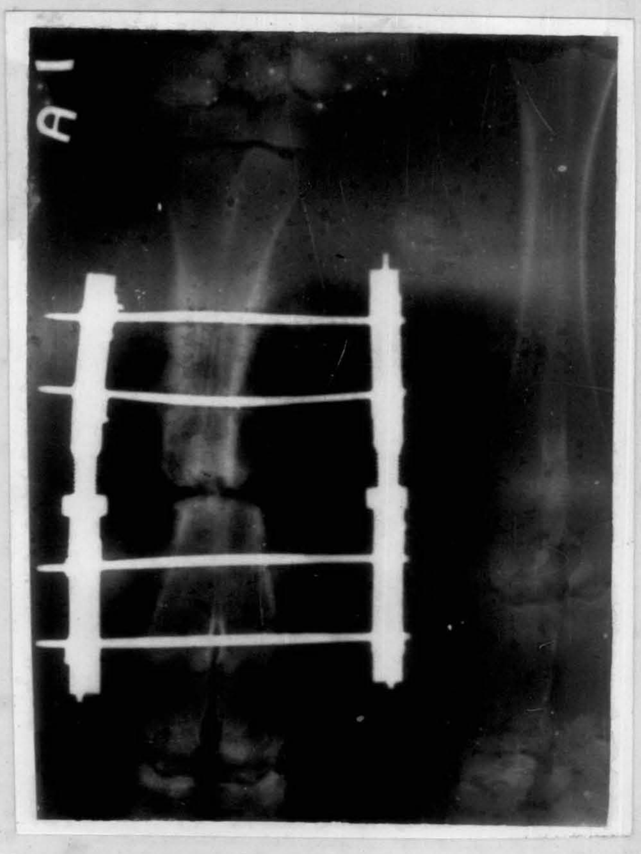

A1

Fig.14. Photograph of harvested left metacarpal (operated) bone and right metacarpal (normal) bone in Group I (Dorsal view)

Fig.15. Photograph of harvested left metacarpal (operated) bone and right metacarpal (normal) bone in Group I (Palmar view)


camlin

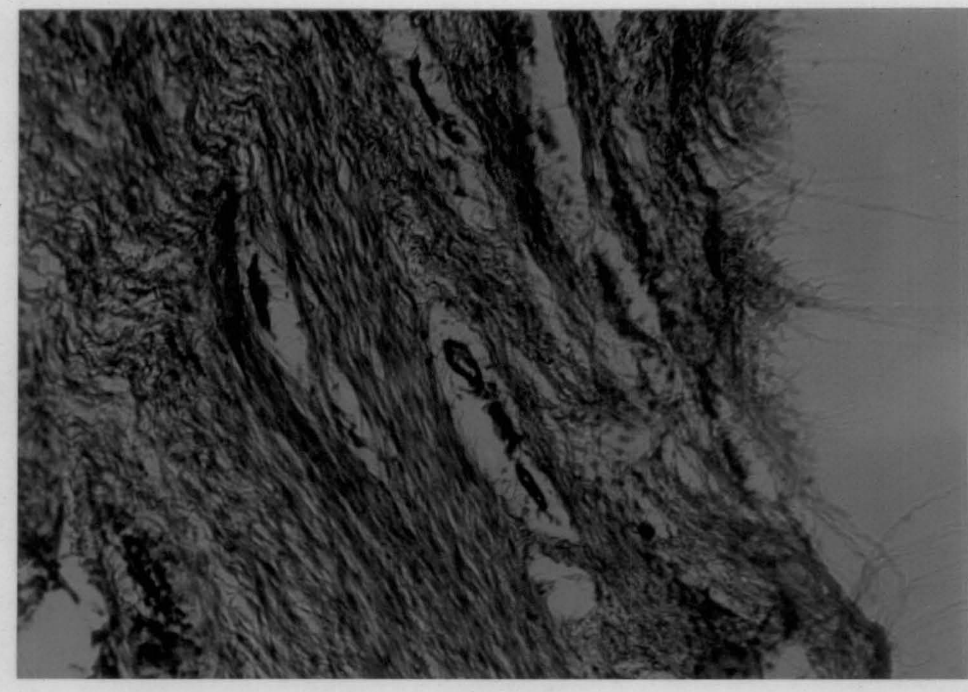

camlin

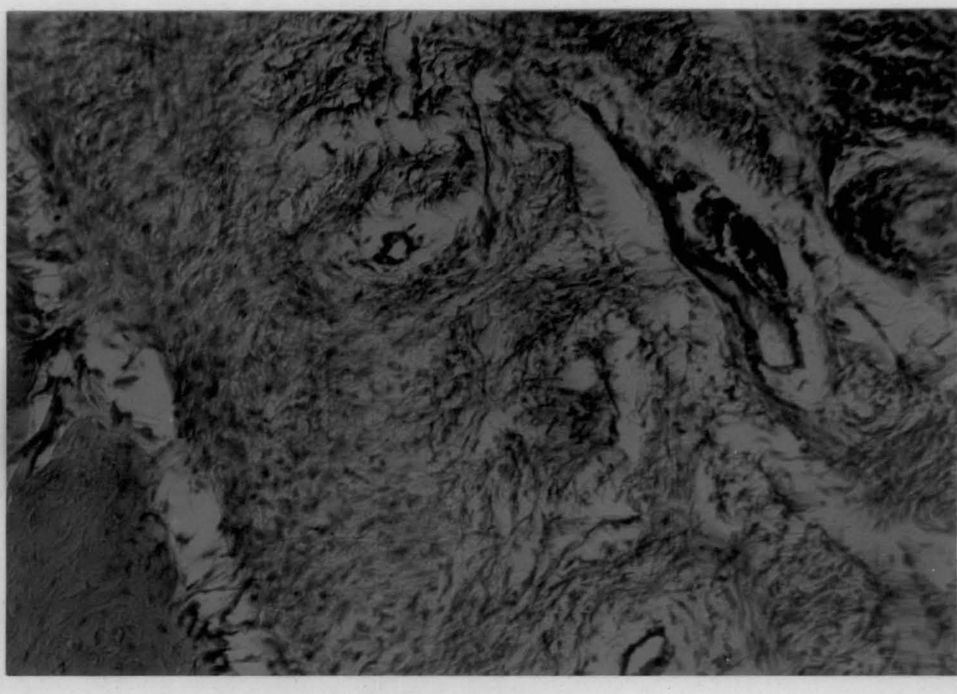
Fig.16. Skiagram of the harvested (operated and normal) bones showing lengthened operated bone with interfragmentary gap (Group I)


G1A
L

Fig.17. Photomicrograph of the callus on 45th day in Group I showing connective tissue proliferation with new trabecular bone formation (H&E x250)

Fig.18. Photomicrograph of the callus on 45th day in Group I. Vascularization of the callus with infiltration of lymphocytes (H&E x250)





GROUP II

The average bodyweight of animals was 86.33 ± 8.36 kg. All the animals were sedated by administering two per cent xylazine at the rate of 0.2 mg/kg bodyweight intramuscularly. The sedation was observed within 7.33 ± 0.61 minutes and the effect persisted for 54.83 ± 2.50 minutes. Half the dose was repeated when animal showed signs of recovery (Table 7). Regional analgesia of the operated limb was effected by brachial plexus block using two per cent solution of 10-15 ml lignocaine hydrochloride. The effect persisted for 37.17 ± 2.12 minutes (Table 8).

Physiological observations (Table 9)

Postoperative increase in rectal temperature was noticed in all the animals upto 15th day and thereafter it gradually reduced to normal. An increase in pulse rate was noticed in all the animals upto the 15th day and the rise was significant ($P<0.05$) on second postoperative day. Marginal increase in respiration rate was noticed in all the animals.

Haematological observations (Table 10)

Total erythrocyte count was seen increased by 24 h after the operation, though not significant and thereafter it decreased to normal limits. The total leukocyte count was seen increased by 24 h and persisted throughout the period of observations. By the 7th day, the increase was maximum though not significant.

The haemoglobin concentration was seen reduced throughout the period of observation, postoperatively. The packed cell volume was seen increased by 24 h following the operation and the increase persisted throughout the period of observation, and yet it was not significant.

The neutrophil count was seen increased with relative decrease in lymphocyte count upto the 7th postoperative day and thereafter the counts returned to the normal limits. The eosinophil count was seen decreased upto 28th postoperative day and by 42nd day it increased to normal limit. The variations in monocyte and basophil counts were marginal.

Clinical observations (Table 11)

All the animals could get up unassisted and were able to walk with limping within 24 h after surgery. They were able to bear weight on the limb within 24 h to three days.

First **week**

All the animals favoured the fractured limb with toe pointing and the limb had oedema from knee downwards. Nodding of head and limping were seen in all animals. Stumbling was observed in three animals (II/2, II/3, II/4). Signs of pain were noticed in all animals. Angulation of limb was noticed in two animals (II/1, II/6). The external fixators were intact in all the animals.

Second week

All the animals favoured the fractured limb with toe pointing. Nodding of head and limping persisted. Stumbling was observed in three animals (II/2, II/3, II/4). The oedema was more evident in three animals (II/1, II/3, II/4). Angulation of limb was observed in two animals (II/1, II/6). Oozing of purulent discharge from pin tracts and fracture site was noticed in two animals (II/3, II.4). The external fixators were intact in all animals.

Third week

Favouring of the fractured limb was noticed only in three animals (II/3, II/4, II/6). Nodding of head and limping persisted in all the animals. Occasional stumbling was noticed in three animals (II/2, II/3, II/4). The oozing of discharge persisted in two animals and there was well developed edema (II/3, II/4). Angulation of the fractured limb was seen reduced in two animals (II/1, II/6). The external fixators were intact. Signs of pain were observed in three animals (II/2, II/3, II/4).

Fourth week

Favouring of the fractured limb with toe pointing was more marked in three animals (II/3, II/4, II/6). Nodding of head and limping persisted in four animals (II/2, II/3, II/4, II/6) and there was oozing of discharge in them. Occasional stumbling was seen in one animal (II/4). The external fixators became loose and the pins were seen bent in two animals (II/3, II/4).

Fifth week

Favouring of the fractured limb with pointing of toe was observed in two animals (II/4, II/6). Nodding of head and limping were observed in three animals (II/2, II/4, II/6). Oozing was seen reduced and the oedema was less marked in the animal II/4. The external fixator was loose in two more animals (II/2, II/6). Bending of pins was noticed in two animals (II/3, II/4).

Sixth week

Two animals (II/4, II/6) favoured the fractured limb. Nodding of head and limping were observed in one animal (II/4). The oedema was more marked in one animal (II/4). The fixator was found loose in one more animal (II/5).

Radiographic observations

First day

Radiogrpahs taken immediately after the operation revealed perfect alignment of fragments in three animals (II/3, II/4, II/5) (Fig.19) and partial displacement of the fragments with small gap in others.

Fifth day

Radiographs revealed perfect alignment of fragments in three animals (II/3, II/4, II/5). The displacement persisted in the other animals.

Fifteenth day

Bone fragments were seen retracted in all animals (Fig.20). Mild osteolytic changes of the cut ends of each segment was observed in two animals (II/3, II/5) and it was more evident in animal II/4. A complete radiolucent area was seen at the gap. Bending of the pins was seen in two animals (II/3, II/4).

Thirtieth day

The fragments were in position. Callus was seen perpendicular to the fragments. Definite column of longitudinally oriented callus was seen extending from each cut surface towards the central transverse radiolucent zone (Fig.21). Bending of the pin and osteolytic changes were seen in two animals (II/3, II/4).

Forty fifth day

The fragments were in position. There was well developed longitudinal columns of callus extending from each cut ends with less radiolucent zone in the centre of the gap in two animals (II/2, II/5) (Fig.22). In two animals (II/1, II/6) there was marked radiolucent area at the centre of the gap. There was no visible callus in one animal (II/4), but had osteolytic area at the cut edges of the bone fragments. Bending of the pins was seen in one animal (II/4). The callus was not completely united in all the animals. Extensive periosteal callus was seen all around the bone.

Gross evaluation of the harvested bone

There was well developed callus at the gap and there was no mobility of the fragments in harvested bones of all animals except in two (II/3, II/4) (Fig.23 and 24). The proliferation of medulla was extensive in all animals except in animal II/3. There was a bluish necrosed area seen at the cut edges of the fragments and also in interfragmentary gap in one animal

(II/3). The harvested bones of two animals (II/1, II/6) had mild degree of angulation.

Radiograph of the harvested bone

Displacement of the fragments were seen on the radiograph of the harvested bone in two animals (II/1, II/6). Radiodense areas were seen from cut ends of each segment and radiolucent area at the centre of the gap with few sites of radiodense zones indicating that the callus was not united completely (Fig.25). Extensive periosteal callus was seen all around the bone. Pin tracts were seen as radiolucent osteolytic areas at the cut ends of each fragments with no visible callus in animals II/3 and II/4.

Radiographic measurement of length was taken from the most proximal and most distal articulations. It was 17.2 ± 0.23 in the right normal metacarpal bone and was 18.05 ± 0.23 in the operated left metacarpal bone on 45th postoperative day (Table 12).

Histological observations

The proliferation of fibrous tissue with osseous trabeculae formation was noticed in the callus of all animals except in two (II/3, II/4). The callus showed zones of newly formed fibrous tissues with new trabecular bone extending from the surface of the cortical bone into the callus (Fig.26).

The trabeculae were irregular and numerous with abundant branching, indicating that the callus was still cancellous in nature. There was well developed blood vessels with increased lumen, indicating that the vascularization of the callus was started. Accumulation of lymphocytes were seen and there was poorly organised osteoid, with abundant osteons, woven bones and cartilage (Fig.27).

Physical measurements of the limb and the harvested bones

The measurement of the operated limb (in cm) taken from shoulder joint to coronet was 56.77 ± 1.07 before operation and it was 57.58 ± 1.11 on 45th postoperative day. The measurement taken from knee joint to fetlock joint was 17.88 ± 0.27 before operation and it was 18.78 ± 0.21 on 45th postoperative day. The circumference at the fracture site was 10.87 ± 0.30 before operation and it was 12.32 ± 0.18 on 45th postoperative day. The length taken from the right normal harvested metacarpal bone was 17.33 ± 0.24, it was 18.15 ± 0.25 in operated left metacarpal bone.

Table 7. Induction time, duration of sedation and period of recovery (in min) following administration of xylazine in calves (Group II)

n=6

Animal No.	Body weight (kg)	Quantity of xylazine used (mg)		Induction time (min) after Ist Admn.	Duration of sedation (min)			Recovery period
		Ist admn.	IInd admn.		After Ist admn.	After IInd admn.	Total	
II/1	80	16.0	10.0	7	48	70	118	55
II/2	62	12.4	12.4	7	65	62	127	35
II/3	120	24.0	15.0	6	58	80	138	50
II/4	100	20.0	15.0	6	53	61	114	58
II/5	76	15.2	10.0	10	55	73	128	45
II/6	80	16.0	10.0	8	50	72	122	60
	86.33± 8.36	17.27± 1.67	12.07± 1.00	7.33± 0.61	54.83± 2.50	69.67± 2.93	124.50± 3.46	50.50± 3.82

Table 8. Time of induction and duration of regional analgesia (in min.) following brachial plexus block with lignocaine hydrochloride solution in calves (Group II)

n=6

Animal No.	Body weight (kg)	Quantity of lignocaine hydrochloride used (ml)			Total quantity used (ml)	Time of induction after Ist administration	Duration of regional analgesia (min)			Total duration of analgesis
		Ist administration	IInd administration	IIIrd administration			After Ist administration	After IInd administration	After IIIrd administration	
II/1	80	15	5	5	25	6	39	40	32	111
II/2	62	10	10	10	30	4	35	38	25	98
II/3	120	15	10	5	30	4	40	25	30	95
II/4	100	15	10	5	30	6	28	35	35	101
II/5	76	15	5	5	25	5	38	26	32	96
II/6	80	15	10	5	30	6	43	35	25	103
	86.33± 8.36	14.17± 0.83	8.30± 1.05	5.83± 0.83	28.33± 1.05	5.17± 0.40	37.17± 2.12	30.67± 2.43	29.83± 1.66	97.67± 2.59

Table 9. **Rectal temperature, pulse rate and respiration rate before surgery and on different postoperative periods in calves (Group II) (Mean±SE)**

n=6

Parameters	Postoperative intervals (day)													
	0	1	2	3	4	5	6	7	8	9	10	15	30	45
Temperature (°C)	38.40± 0.09	39.01± 0.14	39.22± 0.10	39.13± 0.10	39.08± 0.05	38.99± 0.17	39.02± 0.16	39.02± 0.15	39.02± 0.15	39.01± 0.15	38.78± 0.07	38.48± 0.09	38.42± 0.13	38.60± 0.08
Pulse rate (per minute)	62.57± 1.13	91.33± 4.94	92.00± 2.25	85.43± 2.15	84.33± 5.38	82.33± 2.75	91.83± 4.89	83.33± 5.88	84.33± 3.67	83.00± 5.56	73.00± 2.82	70.28± 2.28	62.67± 1.52	64.00± 3.47
Respiration rate (per minute)	20.83± 1.11	27.33± 0.84	28.00± 1.15	25.50± 1.34	25.33± 1.98	24.67± 1.33	26.86± 1.14	25.75± 1.27	25.00± 1.84	24.17± 1.38	23.33± 1.61	22.87± 1.28	22.07± 0.99	20.80± 0.93

Table 10. Haemogram before surgery and on different postoperative periods in calves (Group II) (Mean±SE)

n=6

Parameters	Postoperative intervals					
	Before operation	After 24 h	7th day	14th day	28th day	42nd day
Total erythrocyte count ($10^6/mm^3$)	7.48±0.45	7.61±0.55	7.16±0.56	6.93±0.41	7.07±0.34	7.16±0.30
Total leukocyte count ($10^3/mm^3$)	9.35±0.72	9.43±0.61	10.10±0.78	9.78±0.76	9.66±082	9.80±0.92
Haemoglobin concentration (g/dl)	10.60±0.59	9.92±0.46	9.80±0.57	9.60±0.44	9.30±0.38	9.10±0.52
Packed cell volume (%)	36.84±2.85	39.33±2.22	37.50±2.84	35.33±2.60	37.17±2.90	35.00±2.48
Differential count						
Neutrophils (%)	26.67±2.55	30.33±1.56	32.17±2.57	25.50±1.96	26.17±1.51	26.00±2.68
Lymphocytes (%)	70.83±2.01	67.83±1.82	66.83±2.30	73.50±1.86	72.33±1.25	71.20±2.60
Monocytes (%)	1.00±0.45	1.17±0.31	0.51±0.22	0.17±0.17	1.00±0.45	1.17±0.40
Eosinophils (%)	1.33±0.42	0.67±0.42	0.50±0.22	0.83±0.31	0.67±0.42	1.00±0.52
Basophils (%)	0.00	0.00	0.00	0.00	0.00	0.17±0.17

Table 11. Observations on clinical symptoms and complications following transfixation at different postoperative intervals (in weeks) in calves (Group II)

n=6

Animal No.	Favouring the fractured limb (persisted upto)	Pain (persisted upto)	Stumbling (persisted upto)	Nodding of head and limping (persisted upto)	Oedema (persisted upto)	Angulation of limb (persisted upto)	Pin bending	Pin/ fixator loosening	Pin tract infection	Fracture site infection	Remarks
II/1	2	2	-	3	2	3	-	-	-	-	-
II/2	2	4	3	5	1	-	-	5	-	-	-
II/3	4	4	3	4	4	-	4	4	2-4	2-4	-
II/4	6	4	4	6	6	-	4	4	2-5	2-5	-
II/5	2	2	-	3	1	-	-	6	-	-	-
II/6	6	1	-	5	1	3	-	5	-	-	-

Table 12. Measurements of the operated limbs, before operation and on 45th postoperative day and the harvested operated and opposite normal metacarpal bones (Group II)

n=6

Animal No.	Body weight (kg)	Measurement of the limb (in cm)						Measurement of the metacarpal bone (in cm)			
		Before operation			On the 45th postoperative day			On 45th postoperative day			
								Harvested bone		Radiographic measurement	
		Shoulder to coronet	Knee joint to fetlock joint	Circumference of Midshaft region of metacarpus	Shoulder to coronet	Knee joint to fetlock joint	Circumference of Midshaft region of metacarpus	Rt limb (Normal)	Lt limb (Operated)	Rt limb (Normal)	Lt limb (Operated)
II/1	80	57.5	18.0	11.3	58.3	19.2	12.5	17.7	18.7	17.7	18.6
II/2	62	52.5	17.3	10.3	53.2	18.7	11.6	16.7	17.6	16.5	17.5
II/3	120	60.0	17.0	11.0	60.8	18.2	12.5	16.8	17.7	16.8	17.5
II/4	100	57.5	18.4	12.0	58.3	19.6	12.8	18.2	19.0	18.0	18.8
II/5	76	55.0	17.8	10.0	55.7	18.4	12.0	17.0	17.6	17.0	17.8
II/6	80	58.1	18.8	10.6	59.2	18.6	12.5	17.6	18.3	17.4	18.1
	86.33± 8.36	56.77± 1.07	17.88± 0.27	10.87± 0.30	57.58± 1.11	18.78± 0.21	12.32± 0.18	17.33± 0.24	18.15± 0.25	17.20± 0.23	18.05± 0.23

Fig.19. Skiagram of the left metacarpus, immediately after application of the fixator showing the fragments in apposition (Group II)

Fig.20. Skiagram of the left metacarpus immediately after termination of the traction showing the fragments retracted (Group II)

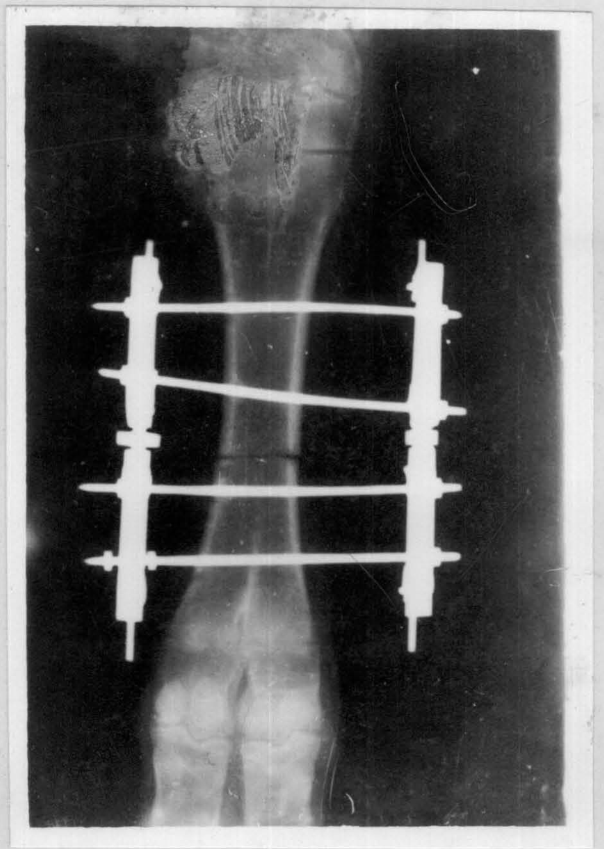
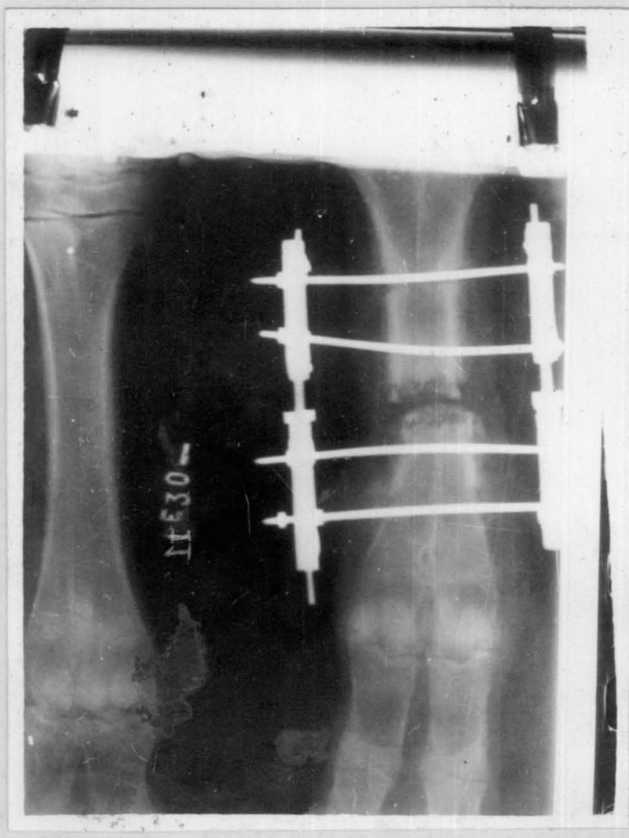


Fig.21. Skiagram of the left metacarpus, 15 days after termination of the traction showing radiodense areas from the cut ends of the both the fragments (Group II)

Fig.22. Skiagram of the left metacarpus, 30 days after termination of the traction



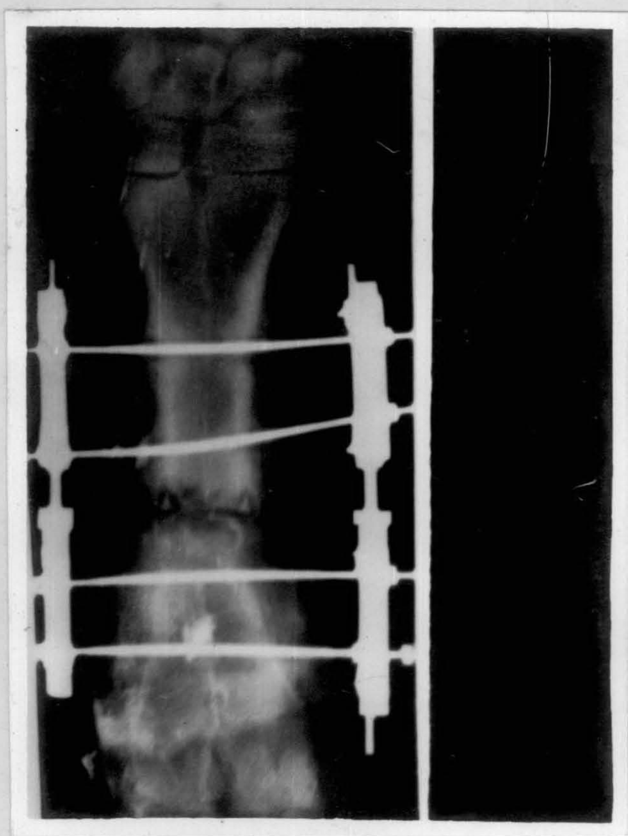


Fig.23. **Photograph of harvested left metacarpus (operated) and right metacarpus (normal) in Group II (Dorsal view)**

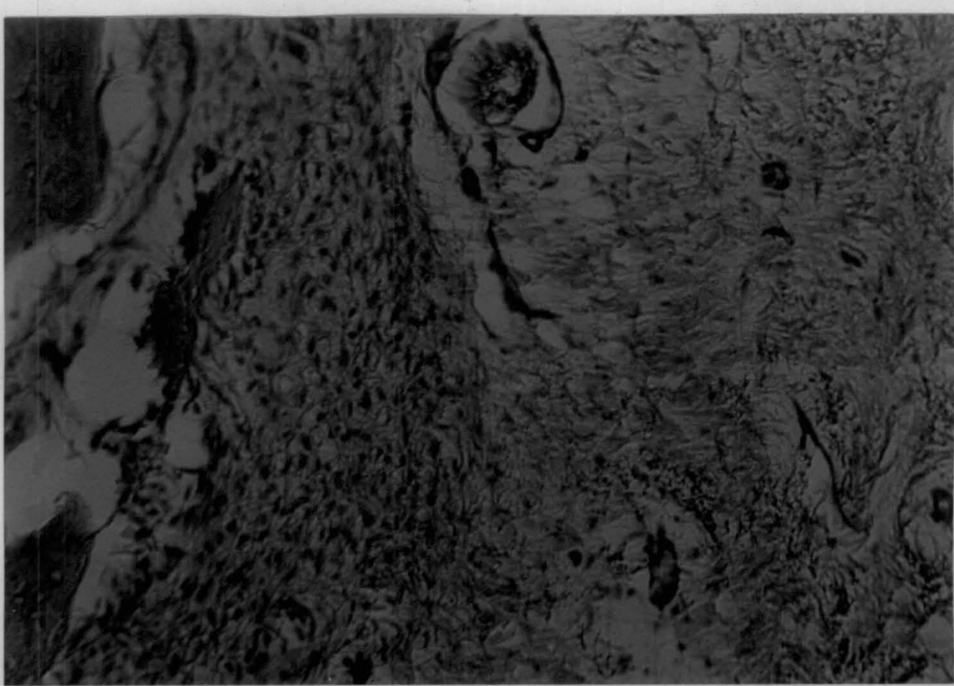
Fig.24. **Photograph of harvested left metacarpus (operated) and right metacarpus (normal) in Group II (Palmar view)**

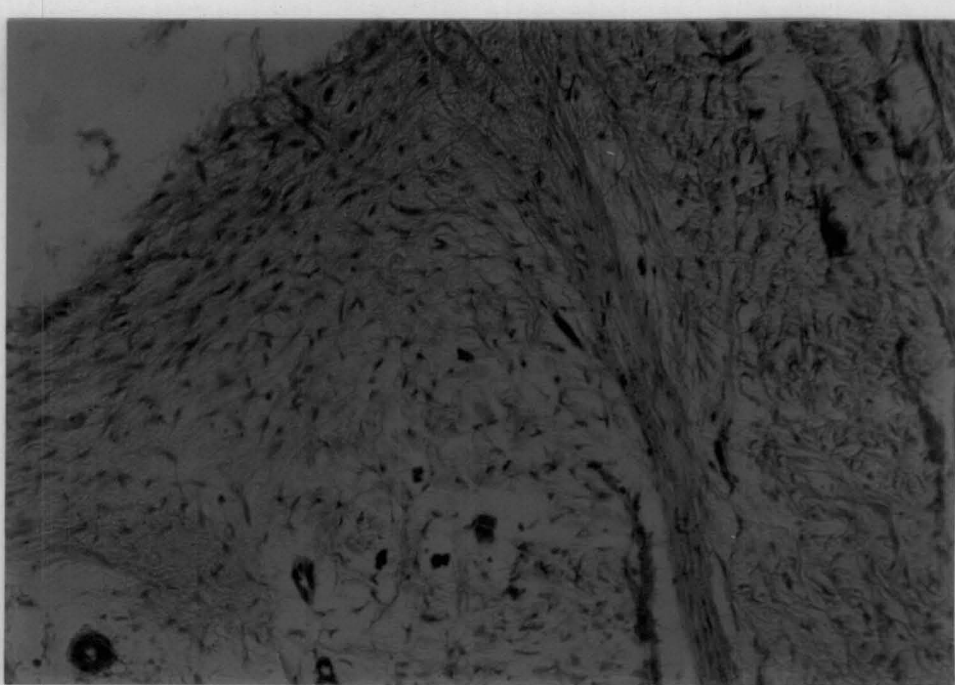
Fig.25. Skiagram of the harvested (operated and normal) bone (Group II)


2E

Fig.26. Photomicrograph of the callus on 45th day in Group II showing newly formed fibrous tissue with new trabecular bone (H&E x250)

Fig.27. Photomicrograph of the callus on 45th postoperative day in Group II showing well developed blood vessels and cartilage formation (H&E x250)





Discussion

DISCUSSION

The experimental study was conducted in 12 apparently healthy crossbred bull calves aged six to twelve months and weighed 60 to 120 kg. The animals were randomly divided into two groups viz. group I and group II, consisting of six animals each. The surgical procedures were carried out under xylazine (@ 0.2 mg/kg) sedation and brachial plexus block using two per cent lignocaine solution (10-15 ml). In Group I, transverse osteotomy was performed at the mid-shaft region of the metacarpal bone. The bone was immobilized with the help of locally fabricated full pin transverse fixation device. From the sixth day onwards, the bone fragments were retracted in opposite directions at the rate of 1 mm gap/day for 10 days, so as to attain 1 cm gap between the fragments. In group II, in addition to the immobilization and retraction procedures as in group I, partial tenotomy of the flexor tendons was also performed on the sixth day, before commencing traction.

Anaesthesia

In the present study, sedation with xylazine at the rate of 0.2 mg/kg bodyweight IM followed by brachial plexus block using two per cent solution of 10-15 ml lignocaine hydrochloride was found satisfactory for the surgical manipulations in the forelimb of calves. George (1993) had reported satisfactory sedation in calves following the administration of xylazine at the rate of 0.2 mg/kg bodyweight I/M. For attaining regional analgesia of the forelimb in cattle, Westhues and Fritsch (1964) had recommended brachial plexus block as an effective method. For the transfixation of the metacarpal bones in buffaloe calves, chloralhydrate narcosis with brachial plexus block was reported as satisfactory (Sahay and Khan, 1976).

Physiological observations

Postoperatively an initial increase in rectal temperature, followed by gradual decrease to normal limits was noticed in both the groups. Increase in pulse rate was noticed in both the groups and the increase was significant ($P<0.05$) on the second postoperative day in group II. The increase in respiration rate was marginal in both the groups.

Haematological observations

The total erythrocyte count was seen increased by 24 h in both the groups and thereafter it gradually reduced to normal limits. The total leukocyte count was seen increased by 24 h and the increase was maximum by the 7th day in both the groups. Thereafter the increase persisted throughout the period of observation. The haemoglobin concentration was seen reduced in both the groups throughout the period of observation. The packed cell volume was seen increased by 24 h in both groups and thereafter the increase persisted throughout the period of observation. There was an increase in neutrophil count with relative decrease in lymphocyte count upto the 7th postoperative day in both the groups and thereafter the counts returned to the normal limits. There was decrease in eosinophil count, but was within normal range. The variations in monocyte and basophil counts were only marginal in both groups.

The variations observed in the physiological parameters and haemogram were due to the systemic inflammatory response elicited by the tissue during the early phase of healing process (Duncan and Prasse, 1986). The spontaneous return of the parameters to normal limit proved that the health of the animals had not been affected and the technique adopted had not caused any serious systemic reaction.

Clinical observations

All the animals were able to get up unassisted and were able to walk with limping within 24 h after surgery. They were able to bear the weight on the limb within 24 h to three days. Connell (1974) also reported that the animals were ambulatory immediately after transfixation.

Favouring the limb with pointing of toe was observed in all the animals of both the groups. In two animals from each group, it persisted throughout the period of observation, because of infection at the fracture site and severe displacement. In one animal of group I, it was very pronounced. Kostlin *et al.* (1990) and Singh *et al.* (1984) had reported displacement of the fragments and infection as complications during fracture repair. Mohanty *et al.* (1970) after evaluating the treatment adopted for the repair of fractures in experimental and clinical cases, found that after pinning, infection was a frequent complication, sometimes as high as 25 per cent.

Stumbling and signs of pain were observed in two animals in group I and three animals in group II for a period varying from second to fourth week. Nodding of head and limping were observed in all the animals in both the groups for a period varying from third to sixth week. Oedema was observed throughout the period of observation in all the animals and was more evident in two animals each in group I and group II.

Angulation of the limb was observed in three animals of group I and two animals of group II. Paley (1991) stated that the axial deviation could be due to imbalance between muscle forces on different sides of the bone and the direction of deviation depended upon the bone involved and the level of the osteotomy. It can be prevented by placing trans-osseous wires 5° to 10° inclined to the opposite direction of the expected deviation. Forell and Schwanz (1993) reported that better cosmetic results were obtained in dogs where the postoperative limb position was within a range of neutral to 4° valgus.

Infection at the pin tract and fracture site were observed in one animal of Group I and in two animals of Group II. Singh *et al.* (1984) and Forell and Schwanz (1993) had also reported pin tract infection and fracture site infection as the common postoperative complications in transfixation pinning. In the present study, the intensity of local infection observed was more in Group II than in Group I, which probably due to additional manipulations during tenotomy procedure on the sixth postoperative day. Apart from this, there was no significant difference between the two groups.

The external fixators were found loose in five animals of each group during a period varying from two to six weeks. Brinker *et al.* (1990) achieved stiffness of the external fixation by using three or four pins per fragment. Bending and loosening of pins were less commonly encountered when three to four pins were used per fragment. Sahay and Khan (1976) had not encountered loosening of pin and displacement when self polymerising acrylic agents were used for connecting the transfixation pins.

The functional status of the limb was not altered in those animals where complications were not observed. Villa (1991) recommended that in limb lengthening, distraction at the rate of one millimeter per day can be achieved without interruption of the function of the limb. Aronson (1991) suggested that the rate of distraction should remain with a range of one half to two millimeters per day, averaging one millimeter per day. Latte (1995) also successfully subjected dogs for bone lengthening from 9-60 mm without complications.

From the clinical signs it was observed that all the animals of both the groups were ambulatory immediately after immobilization with fixator and in uncomplicated cases, a well developed, firm callus was present, though the gap was radiographically not united.

Radiographic observations

Radiographic observations were recorded at different postoperative intervals. Radiographs taken immediately after surgery revealed that there was perfect apposition and alignment of fractured fragments in two animals of group I and three animals of group II. In the other animals, the fragments were seen partially displaced. By postoperative day 5 (before the beginning of traction) the observations were similar.

By postoperative day 15 (immediately after termination of traction), the fragments were seen retracted in all the animals of both the groups but, there was partial displacement of fragments in all the animals of group I and in three animals of group II. Radiodense zones were seen on the cut edges of both the fractured fragments. Extensive periosteal callus was observed on either side of pins in two animals of group I. Osteopenia of the cut edges were seen in two animals of group II.

By postoperative day 30 (fifteen days after termination of traction) radiographic evidence of longitudinally oriented osseous callus extending from each cut surface towards the central transverse radiolucent zone was observed in four animals of each group. Osteolytic changes were observed in one animal of group I and two animals of group II. Pins had bent in two animals of group II. By postoperative day 45 (30 days after termination traction) callus formation was visible at the interfragmentary gap, but it was not seen completely united at the centre of the gap in both the groups. Bending of the pins was not observed in any of the animals in group I but was seen in two animals of group II.

Singh and Nigam (1975) also reported that though there were signs of callus formation during fracture repair radiographically the fracture gap was visible even at the end of sixth week. Excess periosteal callus was observed in all animals. Van Vechten and Vasseur (1993) reported that the callus was ossified completely and the ostectomy site was not visible 13 months after surgery.

In the present study, the callus formation bridging the fragments was observed by the thirtieth day but was not completely united even after 45 days. Clinically the callus was well developed and firm and the fragments were immobile. Bending of the pins observed was probably due to the smaller size of the pins in relation to the bodyweight of the animal. Fessler and Amstutz (1974) stated that the fracture line would be radiographically evident even if the fracture got clinically stabilized. Ackerman and Silverman (1978) had also reported that clinical healing of fracture will take place before the radiographic evidence of fracture healing became apparent and hence clinical observations will be the better assessment for fracture healing. In the present study, the retraction of the fragments (1 cm in 10 days) has created a larger gap between the fragments and might be responsible for the delay in ossification of the callus.

Gross evaluation of the harvested bone

Angulation of the harvested bone was severe in one animal of group I and was mild in two animals of group II. There was well developed callus and there was no mobility of the fragments in four animals of each group. Non union was observed in one animal of each group. Latte (1995) also reported 12 per cent failure in lengthening of bone.

Histological observations

There was well developed primary callus characterised by fibrous tissue proliferation and osseous trabeculae formation. New bone formation could be seen in between the bony fragments, but the newly formed bone was cancellous in nature. Aronson (1991) studied the histology of distraction osteogenesis and reported that by 14th day, the distraction gap was bridged by fibrovascular network. By 21st day new bone was first seen formed from the cut surfaces of the bone. By 28th day, the central region of the osteogenic area remained as a fibrous interzone, containing trace amounts of calcium. By 77th day, the bone columns bridged across the fibrous interzone and the osteogenic area had remodeled.

Radiographic and histological findings had revealed normal healing pattern without any complication in four animals from each group and the functional status of the limb was not seen altered in these animals.

Physical measurements of the limb and the harvested bones

The increase in limb length ranged from 0.8 to 1.5 cm in Group I and 0.7 to 1.1 cm in Group II. The increase in the length of the operated metacarpal bone ranged from 0.6 to 1.00 cm in both the groups. The radiographic measurement of the metacarpal bone revealed that the increase in the bone length was ranged from 0.5 to 1.1 cm in group I and 0.6 to 1.0 cm in group II. Though the gap between the fragments were approximately 1 cm after completing traction, it was observed that at the end of the observation it was reduced to less than 1 cm in certain cases. This reduction in length observed is probably due to the bending of the connecting rods of the transfixation device caused by increase in bodyweight of the animal. No additional advantage had been observed when partial tenotomy was combined with osteotomy and traction for lengthening of the limb.

Latte (1995) opined that partial tenotomy of the superficial flexors could be beneficial in bone lengthening procedures in dogs. Canuti (1991) opined that for lengthening of the limb, tenotomy should be considered as a last resort. From the observations in the present study it could be inferred that partial tenotomy of the flexor tendon is not necessary for lengthening the limb, but may help in those cases where the shortening of the limb is due to bone defects accompanied by contracted tendons.

Full pin transverse fixtor

In the present study, the locally fabricated full pin transverse fixator used was found satisfactory for the lengthening procedures. It facilitated traction and provided rigid immobilization of the fragments. The calves tolerated the fixator well. There was no damage to the fixator during the period of observation.

The use of Ilizarov technique in large animals is more complex due to the mechanical problems of size and weight. Moreover the Ilizarov apparatus is costly but the fixator used in the present study proved to have the advantages of ease of fabrication, ease of application, lighter weight, less trauma to the bone and better adaptability for different sizes of calves coupled with economic affordability to the livestock farmer.

Summary

SUMMARY

The experimental study was conducted in 12 apparently healthy crossbred bull calves aged six to twelve months and weighing 60 to 120 kg. The animals were randomly divided into two groups viz. Group I and II, consisting of six animals each. The surgical procedures were carried out under sedation with xylazine (@ 0.2 mg/kg) and brachial plexus block using two per cent lignocaine solution 10-15 ml, which was found to be satisfactory. In Group I, transverse osteotomy was performed at the mid-shaft region of the metacarpal bone. The bone fragments were immobilized with the help of locally fabricated full pin transverse fixation device. From the sixth day onwards, the bone fragments were retracted in opposite directions at the rate of 1 mm gap/day for 10 days, in order to attain 1 cm gap between the fragments. In group II, in addition to the immobilization and retraction procedures as in group I, partial tenotomy of the flexor tendons was performed on the 6th day. All the animals were maintained for 45 days and physiological, haematological, clinical, radiographical observations and measurements of limbs were recorded. On the 45th day all the animals were sacrificed and the metacarpal bones were harvested and subjected for gross and histological studies, measurement of the harvested bones was also carried out. The data were analysed statistically.

Postoperatively an initial increase in rectal temperature, followed by gradual decrease to normal limits was noticed in both the groups. Increase in pulse rate was noticed in both the groups and the increase was significant ($P<0.05$) on the second postoperative day in group II. The increase in respiration rate was marginal in both the groups.

The total erythrocyte count was seen increased by 24 h in both the groups and thereafter it reduced to normal limits. The total leukocyte count was seen increased by 24 h with maximum increase by the 7th day in both the groups and the increase persisted throughout the period of observation. The haemoglobin concentration was seen reduced in both the groups throughout the period of observation. The packed cell volume was seen increased by 24 h in both the groups and the increase persisted throughout the period of observation. There was an increase in neutrophil count with relative decrease in lymphocyte count upto the 7th postoperative day in both the groups and the values returned to the normal limits. There was decrease in eosinophil count but was within normal range. The variations in monocyte, and basophil counts were only marginal in both groups.

All the animals were able to get up unassisted and were able to walk with limping within 24 h after surgery. They were able to bear the weight on the limb within 24 h to three days.

Favouring of the limb with the toe pointing was observed in all the animals of both the groups. In two animals from each group it persisted throughout the period of observation. In one animal of group I, it was pronounced.

Stumbling and signs of pain were observed in two animals of group I and three animals of group II for a period varying from second to fourth week. Nodding of head and limping was observed in all the animals of both the groups for a period varying from third to sixth week. Oedema was observed throughout the period of observation in all the animals and was more evident in two animals each of group I and II. Angulation of the limb was observed in three animals of group I and two animals of group II. Suppuration at the pin tract and fracture site were observed in one animal of group I and in two animals of group II.

The external fixators were found loose in five animals of each group during a period varying from two to six weeks.

The functional status of the limb was not altered in those animals where complications were not noticed.

Radiographs taken immediately after surgery revealed perfect apposition and alignment of fractured fragments in two animals of group I and three animals of group II. In the other animals, the fragments were seen partially displaced.

These observations were similar by postoperative day 5 (before the beginning of traction)

By postoperative day 15 (immediately after termination of traction), the fragments were seen retracted in all the animals of both the groups and there was partial displacement of fragments in all the animals of group I and in three animals of group II. Radiodense zones were seen on the cut edges of both the fractured fragments. Extensive periosteal callus was seen on either side of pins in two animals of group I. Osteopenia of the cut edges were seen in two animals of group II.

By postoperative day 30 (fifteen days after termination of traction) radiographic evidence of osseous callus was observed at the ends of the bone fragments in four animals of each group. Osteolytic changes were observed at the ends of the fragments in one animal of group I and two animals of group II. Pins were found bent in two animals of group II. By postoperative day 45 (30 days after termination of traction) callus formation was visible, but was not seen completely united at the centre of the gap in both the groups.

Gross evaluation of the harvested bones revealed the presence of well developed callus with no mobility of the fragments in four animals of each group. Non union was observed in one animal of each group. Severe angulation of the harvested bone was seen in one animal of group I and mild angulation in two animals of group II.

Histological observations revealed well developed primary callus with the fibrous tissue proliferation and osseous trabeculae formation. The trabeculae were irregular and numerous with abundant branching indicating the callus was cancellous in nature.

The operated limb was seen increased in length by 0.8 to 1.5 cm in group I and 0.7 to 1.1 cm in group II. The length of the operated metacarpal bone was seen increased from 0.6 to 1.00 cm in both the groups. The radiographic measurement of the metacarpal bone revealed an increase in bone length ranging from 0.5 to 1.1 cm in group I and 0.6 to 1.0 cm in group II. Though the gap between the fragments were approximately 1 cm after completing traction, it was observed that at the end of the observation it was reduced to less than 1 cm in certain cases.

In the present study, the locally fabricated full pin transverse fixator used was found satisfactory for the lengthening procedures. It facilitated traction and provided rigid immobilization for the fragments. The calves tolerated the fixator well. There was no damage to the fixator during the period of observation.

From the results of the present study, it could be concluded that

(i) the metacarpal bone can be lengthened effectively by osteotomy and traction with or without performing tenotomy

(ii) the fixator fabricated for lengthening procedures of long bones in calves was satisfactory and

(iii) the fixator was effective for immobilisation of long bone fractures in calves.

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EFFECT OF METACARPAL OSTEOTOMY AND TRACTION FOR LENGTHENING OF THE FORELIMB IN CALVES

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ABSTRACT OF A THESIS

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ABSTRACT

The study was undertaken with the objectives of evaluating the effect of osteotomy and distraction osteogenesis for lengthening of the limb and to evolve treatment measures that can be adopted for the correction of shortened limb in calves.

The experimental study was conducted in 12 crossbred bull calves aged six to twelve months and weighing 60 to 120 kg, randomly divided into two groups of six animals each. Under xylazine (@ 0.2 mg/kg) sedation and brachial plexus block (two per cent lignocaine solution 10-15 ml) transverse osteotomy was performed at the mid-shaft region of the metacarpal bone. In group I the limb was immobilized using a locally fabricated full pin transverse fixation device. From the sixth day onwards, the bone fragments were retracted in opposite directions at the rate 1 mm gap/day for 10 days. In group II partial tenotomy of the flexor tendons was performed on the sixth day and immobilization and retraction procedures was adopted as in group I.

Sedation with xylazine followed by brachial plexus block was found satisfactory for the surgical manipulations.

Increase in rectal temperature, pulse rate and respiration rate was noticed following surgery but the increase was within normal range in both the groups. The total erythrocyte and leukocyte counts, and packed cell volume increased whereas the haemoglobin concentration was seen reduced in both the groups following surgery but the changes were within normal limits. Initially there was increase in neutrophil count with relative reduction in lymphocyte count. There was decrease in eosinophil count, but was within normal range. The variations in monocyte and basophil counts were only marginal in both the groups.

All the animals were able to get up unassisted and were able to walk with limping within 24 h after surgery. They were able to bear weight on the limb within 24 h to three days, though there was favouring of the limb with too pointing. Oedema was observed in all the animals and was more evident in those animals where there was infection. In a few animals the complications such as angulation of the limb due to displacement of bone fragments, infection at the fracture site and pin tracts and loosening of pins were noticed. The functional status of the limb was not altered in those animals where complications were not noticed.

Radiographically radiodense zone on the cut edges of the fractured fragments was noticed by 15th postoperative day, evidence of osseous callus by 30th postoperative day and visible callus with a gap at the centre by 45th postoperative day.

The bone fragments were seen firmly fixed with a well developed callus and histological examination of the callus revealed the presence of fibrous tissue proliferation and osseous trabaculae indicating formation of a new bone.

The length of the operated metacarpal bone was seen increased by 0.6 to 1.0 cm when compared to the opposite normal metacarpal bone.

In the present study, the locally fabricated full pin transverse fixator used was found satisfactory for the lengthening procedures. It facilitated traction and provided rigid immobilization for the fragments. The calves tolerated the fixator well. There was no damage to the fixator during the period of observation.