COMPARATIVE EVALUATION OF VETERINARY CUTTABLE PLATE AND LOCKING RECONSTRUCTION PLATE FOR TIBIOTARSUS FRACTURE REPAIR IN ASEEL BIRD

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by

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CERTIFICATE

This is to certify that the thesis entitled **"*COMPARATIVE EVALUATION OF VETERINARY CUTTABLE PLATE AND LOCKING RECONSTRUCTION PLATE FOR TIBIOTARSUS FRACTURE REPAIR IN ASEEL BIRD*"** submitted by **Mr. GURUDEV KARAJAGI**, I.D. No. **MVNK-1926** in partial fulfilment of the requirements for the award of **MASTER OF VETERINARY SCIENCE** in **VETERINARY SURGERY AND RADIOLOGY** of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar is a record of the bonafide research work carried out by him during the period of his study, in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately
Dedicated to
My Parents

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MARCH, 2022 **GURUDEV KARAJAGI**

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LIST OF ABBREVIATIONS AND SYMBOLS

et al.,	and others
°C	Degree Celsius
%	Per cent
/	Per
No	Number
mg	Milligram
Kg	Kilogram
g	Gram
SE	Standard error
mL	Milliliter
±	Plus or minus
W	Watt
p.	Page
pp.	Page to page
kVp	Kilovoltage potential
mAs	Milliampere-seconds
µg	Microgram
IU	International unit
L	Liter
ESF	External skeletal fixator

Introduction

I. INTRODUCTION

Aseel is an Indian breed of game bird. It is distributed particularly in the states of Andhra Pradesh, Chhattisgarh and Odisha. It is used for cock-fighting and meat purpose. There are many varieties of Aseel. Among them are Amroha, Bhaingam, Kilimooku, Lasani, Madras, Mianwali, Reza and Sindhi types. The price of Aseel bird ranges from thousands to lacks which are used for game purpose.

Bennett and Kuzma (1992) reported that tibiotarsus fracture was the most common fracture of leg bone. Wan *et al.* (1994) advocated that avian bones had a tendency to fragment or shatter upon impact due to their brittle nature and because of less soft tissue covering or support to the distal extremities. Wright *et al.* (2018) reported that highest fractures region was in mid-diaphyseal (53%) then followed by proximal third (22%) and distal third (13%) of tibiotarsus diaphyseal fractures.

Carrasco *et al.* (2018) reported that traumatic fractures can occur at the impact location (direct force) or be transmitted through bone or muscle to a distant point (indirect force, e.g., femoral head avulsions or condylar fractures). The energy of the impact may be high or low, causing 'low impact' and 'high impact' fractures respectively. Fix and Barrows (1990) reported that anthropogenic experiences like gunshot wounds, collisions with automobiles or fences, encounters with traps, attacks by dogs or cats were the causes of fracture in birds. Carrasco *et al.* (2018) stated that loss of axial alignment, angulation, rotation and change in length were the clinical signs seen in fractured bone. Fix and Barrows (1990) reported that anthropogenic experiences like gunshot wounds, collisions

with automobiles or fences, encounters with traps, attacks by dogs or cats were the causes of fracture in birds.

Forbes (1998) suggested that two views at right angles should always be taken. The bird might be placed directly on the cassette, using tape and sand bags. Alternatively, the bird might be positioned on a custom-made plexiglass sheet which overlies the plate might employ tapes and straps for patient restraint. Harcourt-Brown (2002) studied those two orthogonal views were useful in diagnosis of fractured limb and also recommended to take whole body radiograph and normal limb along with the fractured limb. Helmer (2006) opined that cross sectional image eliminates overlying structures so objects of interest were more accurately visualised. Computed tomography was best suited for evaluation of bone and air-filled structures.

Gayathri and Sunil (2018) suggested that emergency treatment of shock, haemorrhage and sepsis must be given first. It was important to assess the patient holistically, including diet, husbandry and concurrent medical conditions, without focusing solely on the obvious injuries. Kavanagh (1997) opined that a minimal number of feathers were plucked at the surgical site to reduce body heat loss. The surgical area was scrubbed with chlorhexidine gluconate in warm water to avoid excessive wetting of the feathers.

Krajca and Juranova (1994) reported that the xylazine-ketamine cocktail gave a very fast and smooth induction of anaesthesia associated with deep analgesia, good muscle relaxation and absence of all reflexes and also reported that the xylazine-ketamine cocktail gave a very fast and smooth induction of anaesthesia associated with deep analgesia, good muscle relaxation, and absence of all reflexes.

Method of fracture repair in bird is by cage rest, external fixation, internal fixation, external coaptation as reported by many authors. Among these techniques internal fixation is the most successful and advanced modality.

Sarrau *et al.* (2007) opined that due to the elasticity obtained using a long veterinary cuttable plate alone, it could also be used as a bridging construct and reduced the stress applied to the points of the fixation (the screws and bone). It provided greater interfragmentary micromovements to stimulate a more voluminous callus. Brüse *et al.* (1989) reported that veterinary cuttable plates allowed for placement of multiple screws in relatively short bone fragments on account of the large number of screws per unit length as compared with dynamic compression plates, least contact dynamic compression plates or locking compression plates.

Conzemius and Swainson (1999) reported that reconstructive plates worked well in areas where plate contouring could be difficult and the oval screw holes increased the versatility of the angle at which screws could be placed, however, they were less resistant to bending forces. Ellis and Graham (2002) opined that the most significant advantage of locking reconstruction plates might be that it becomes unnecessary for the plate to have intimate contact with the underlying bone in all areas. As the screws were tightened, they lock to the plate, thus stabilizing the segments without the need to compress the bone to the plate.

Keeping in view of the above facts, the present study was under taken with following objectives.

1. To evaluate and compare the efficacy of veterinary cuttable plate and locking reconstruction bone plates for tibiotarsus fracture repair in Aseel bird.
2. To evaluate the clinical and radiological healing of tibiotarsus fracture repair with veterinary cuttable plate and locking reconstruction bone plates.
3. To assess the intra-operative and post-operative complications in tibiotarsus fracture repair.

Review of Literature

II. REVIEW OF LITERATURE

The available literature on long bone fractures and treatment in birds was reviewed under the following headings.

2.1 Anatomy of long bone in birds

2.2 Incidence of long bone fractures in birds

2.3 Aetiology of long bone fractures in birds

2.4 Clinical signs of long bone fractures in birds

2.5 Clinical evaluation

2.6 Evaluation of fracture in birds with radiography

2.7 Evaluation of fracture in birds with computed tomography

2.8 Pre-operative preparation

2.9 Anaesthetic protocol

2.10 Surgical treatment for tibiotarsus fracture repair

2.11 Implants

2.12 Post-operative care

2.13 Post-operative complications

2.1 ANATOMY OF TIBIOTARSUS IN BIRDS

Nickel *et al.* (1977) stated that the shank bones consist of the tibia and fibula. The tibia is a strong, tubular bone, the proximal row of tarsal bones fused with the distal end therefore termed the tibiotarsus. In fowl and pigeon, the tibiotarsus is longer than the femur by only about a third the length of the latter. The proximal end of the tibia bears two grooved condyles which articulate with the femur. The lateral surface of lateral condyle also articulates with head of fibula. There are two cranial ridges, separated by a wedge groove which has a strong bony bridge, immediately proximal to trochlea, for the passage of tendons of extensor muscles of the toe. The fibula has a prominent head which articulates with the tibia and contacts the lateral condyle of femur. At some distance from the head, the needle like, pointed, thin, body of fibula forms a syndesmotic or synostotic junction with the distinct bony ledge in tibia. It runs distally as a small, narrow ledge on the lateral surface of tibial trochlea. Muscle gastrocnemius consist of three parts, caput laterale on the lateral epicondyle of the femur, caput mediale on the medial epicondyle of the femur, caput tibiale on the caudal surface of the tibia. This muscle inserts proximally on the plantar surface of the tarso-metatarsus. The middle part of the tendon forms a sheath for the tendons of the toe flexors and it extends with them to the toes. Muscle gastrocnemius having function to extend the tarso-metatarsal joint and flex the toe and knee joints. The tibial nerve supplies to gastrocnemius muscle.

Loveridge *et al.* (1993) reported that avian long bones are developed by endochondral ossification. The long bone cells become chondrocytes that secrete extracellular matrix. The external cells develop into a perichondral sheath that consists of an outer layer of fibroblast that is rich with connective tissue and a multiplying inner layer

of mesenchymal cells. These cells hypertrophy over time, accumulating glycogen and producing additional extracellular matrix. There is a simultaneous development of bone vascularity and cell differentiation of the perichondral cell line to osteolysis that secrete a bone collar. This collar gives rise to the calcified bone by osteoblastic expansion. At the centre of this expanding collar, the chondrocytic secretion of alkaline phosphatase allows calcification to occur. The osteoclast cell line erodes the calcified cartilage. Areas formed by osteoclastic erosion fill with cells that form marrow tissue and osteoblasts. Periosteal bone is formed by an ever-expanding bone collar, whereas the marrow cavity is established as the internal trabecula formations are removed.

Harcourt- Brown (2002) reported that tibiotarsus bone is formed by a fusion of the tibia with the proximal row of tarsal bones. The fibula is attached to the tibia at the fibular crest. The arterial supply to the limb runs between the fibula and tibia above and below this crest.

Kubiak and Forbes (2011) reported that the tibiotarsus anatomy predisposed the bone to fracture at a point 2 to 3 cm distal to the tibial crest, which is where the cross-sectional shape of the bone alters proximally from triangular to circular with inherent loss of structural security.

2.2 INCIDENCE OF LONG BONE FRACTURES IN BIRDS

Bennett and Kuzma (1992) reported that tibiotarsus fracture was the most common fracture of leg bone.

Harcourt-Brown (2002) opined that in captive birds, especially birds of prey, the tibiotarsus was the most commonly fractured leg bone. Hawks nearly always break the bone when newly jessed. In these cases, the bone fractures were 2 to 3 mm distal to the fibular crest.

Rodriguez *et al.* (2010) reported that as a result of recently conducted study, it had been found that extremity fractures were the most frequent injuries in wild birds brought to animal hospitals and rehabilitations centres.

Kubiak and Forbes (2011) reported that tibiotarsus fractures were the most common type of orthopaedic injury seen in captive raptors and typically occurred in the first three weeks after a bird was initially tethered.

Carrasco *et al*. (2018) reported that in wild birds high impact injuries, generally resulted in comminuted, displaced and open fractures. Whereas, low impact injuries in active birds produced most often closed simple fractures.

Wright *et al.* (2018) reported that highest fractures region was in mid-diaphyseal (53%) then followed by proximal third (22%) and distal third (13%) of tibiotarsus diaphyseal fractures.

2.3 AETIOLOGY OF LONG BONE FRACTURES IN BIRDS

Wood (1941) reported that birds were subjected through injury, collision or gunshot dangers of fractures of various bones fractures, including wing bones during flight. Fractures of the legs might result from encounters, occasionally with traps or by other

means. Young birds might fall from nests and get caught in branches; fractures were sustained while trying to extricate themselves.

Borman *et al.* (1978) reported that avian bones were thin and brittle because of their high calcium content.

Westfall and Egger (1979) reported that the presence of sparse bone in the metaphyseal region of long bones and fine bony trabeculae throughout the length of bone posed severe threat for intramedullary pinning in avian bone.

Durham (1981) reported that most of the raptors were wild birds from Minnesota and neighbouring states admitted for traumatic injuries resulted into wing fracture caused by collision with powerlines, moving vehicles and injuries from projectiles. They were caught by the leg traps and produced fracture of both legs.

Kuzma and Hunter (1989) stated that avian bones had an increased brittleness because of their high calcium content.

Kuzma (1990) opined that bird bones tended to fragment or shatter upon impact and in birds most of the bones of the distal extremities had little soft tissue for support covered by tendons and skin. Fragments could easily detach from their soft tissue attachment.

Fix and Barrows (1990) reported that anthropogenic experiences like gunshot wounds, collisions with automobiles or fences, encounters with traps, attacks by dogs or cats were the causes of fracture in birds.

Houston (1993) reported that avian bones were thin and brittle and tended to break into fragments upon a variety of natural events like mid-air collisions or fights with other birds.

Wan *et al.* (1994) advocated that avian bones had a tendency to fragment or shatter upon impact due to their brittle nature, and because of less soft tissue covering or support to the distal extremities.

Tully (2002) reported that sexually active females mobilised large amounts of calcium from their skeleton to produce the egg shells during the egg laying process. Excessive egg laying was predisposed female birds to bone fractures.

Hollamby *et al.* (2004) reported that fracture in a bald eagle was due to car accident.

Hoybergs *et al.* (2008) stated that fractures in raptors often occurred during hunting seasons, where high kinetic energy and unpredictable movement resulted in fracture.

Johnston *et al.* (2008) reported that ceiling fan injury was the cause of tibiotarsus fracture in male yellow-naped amazon parrot.

Gayatri and Sunil (2018) reported that the bones of avians had thinner, more brittle cortices and that the pneumatized bones were connected to air sacs. Hence, many avian fractures were comminuted and open fractures in humerus and femur and could lead to subcutaneous emphysema and respiratory infections.

Carrasco *et al.* (2018) reported that fractures occurred due to trauma or pathological weakening of the bone. Various factors might be involved, however, bone weakening,

infection, neoplasia and metabolic bone disease were the more common underlying causes of pathological fractures. On direct forces and indirect forces produces femoral head avulsion or condylar fracture of femur bone.

2.4 CLINICAL SIGNS OF LONG BONE FRACTURES IN BIRDS

Davidson *et al.* (2005) reported unable to fly and crepitus were the clinical signs showed by the bald eagle with coracoid fracture.

Hoybergs *et al.* (2008) observed swelling and wound were the clinical signs at fracture site.

Venugopal *et al.* (2014) reported unstable wing, inability to fly, wound, protrusion of fractured end of bone, pain and crepitus on palpation were the clinical signs in Indian peafowl with a wing fracture.

Carrasco *et al.* (2018) stated that loss of axial alignment, angulation, rotation and change in length were the clinical signs seen in fractured bone.

2.5 EVALUATION OF FRACTURE HEALING

Bush *et al*. (1976) reported that clinically well- aligned stable fracture healed faster in about 3 weeks which was faster than mammalian bone.

Bennett and Kuzma (1992) reported that healing progressed rapidly with good alignment in those birds with only an osteotomy of the radius stabilized with external skeletal fixation. At week 3, motion was no longer palpable at the osteotomy site. In birds with both radius and ulna osteotomies stabilized with external skeletal fixator, motion at

the fracture site persisted until 5 weeks post the osteotomy. After 8 weeks, the osteotomies were more stable. Birds in this group were able to fly 4-6 weeks after removal of the coaptation.

Kestin *et al.* (1992) reported that a gait scoring system for evaluating the prevalence of leg weakness by assessment of the walking ability of broilers were designed into six categories, from completely normal to immobile.

Hollamby *et al.* (2004) reported that after tibiotarsus fracture repair of a bald eagle using interlocking nail, it was seen to bear weight on the affected limb 48 hours post-operatively.

Javdani and Nikousefat (2012) reported that radial and femoral fracture healed within 7 weeks within 7 weeks radial and ulnar fractures had healed in sparrow hock.

Venugopal *et al.* (2014) reported that clinical signs of healing were noticed in the third post-operative week. A stable callus was felt and better usage of the stable operated wing for flight was observed in an Indian peafowl with wing fracture that was stabilized using intramedullary pinning.

Bueno *et al.* (2015) reported that a raptor treated for tibiotarsus fracture with tie in fixator was bearing weight on its limbs after 4 to 5 days after surgery. They also reported that fracture healing was assessed by palpation of the limb. Palpable healing was defined as lack of bone movement at fracture site when gentle pressure was applied and transmittal of rotational forces from the hock joint to stifle joint when twisting forces were applied.

2.6. EVALUATION OF FRACTURE IN BIRDS WITH RADIOGRAPHY

Cooper and kreel (1976) stated that radiography was a well-established procedure for the diagnosis and management of fractures in birds and also gave evidence of non-union, infection and the presence of lead shot fragments. It was not always possible to arrive at a definite diagnosis by radiological examination only and in some cases supporting evidence, based on bacteriology, pathology and other disciplines, was necessary.

James *et al.* (1978) advocated xeroradiography and plain radiographic studies were compared and found both helpful for fracture repair evaluation and visualizing callus formation in birds.

Bennett and Kuzma (1992) reported that in experimentally induced ulnar and humerus fractures in pigeons, both endosteal and periosteal callus were evident radiographically nine weeks post-operatively. Callus formation was better developed in ulna fractures than humerus fractures either because the humerus was pneumatic or because there was a greater degree of instability and displacement with humerus fractures.

Wan *et al.* (1994) reported that on radiographic evaluation a large bridging callus was observed 3 weeks post-operation in the osteotomy site of bird's bone.

Forbes (1998) suggested that two views at right angles should always be taken. The bird might be placed directly on the cassette, using tape and sand bags. Alternatively, the bird might be positioned on a custom-made plexiglass sheet which overlies the plate might employ tapes and straps for patient restraint.

Harcourt-Brown (2002) studied those two orthogonal views were useful in diagnosis of fractured limb and also recommended to take whole body radiograph and normal limb along with the fractured limb.

Orosz (2002) opined that in birds, radiographs were recommended 3 weeks after surgery and then every 2 weeks until the bone had healed.

Williams (2002) reported that in many cage birds relatively small magnification radiography could be employed to enlarge the radiographic images; however, there was an inherent loss of edge sharpness. Magnification radiography was accomplished by increasing the distance between the patient and the film.

Naguib (2017) opined that radiography was the choice for assessment of musculoskeletal system, where long bone fractures were easily visualised.

2.7 EVALUATION OF FRACTURE IN BIRDS WITH COMPUTED TOMOGRAPHY (CT)

Braunstein *et al.* (1986) evaluated that the relative contribution of plain radiographs and computed tomography to the assessment of fracture healing under experimental circumstances. In 15 sheep, midshaft femoral osteotomies were repaired with internal fixation. Radiographs were obtained pre-operatively and immediately post-operatively. Animals were sacrificed at 3 weeks, 6 weeks, 12 weeks, 24 weeks, and 36 weeks after surgery and the femoral specimens were radiographed. After removal of the internal fixation devices, computed tomographic scans of the specimens were performed. By 3 weeks, callus was visible, however at 6 weeks, a trabecular pattern in the callus was seen

on plain films however not on computed tomography. There was progressive organization of the callus on both studies. At 24 weeks, computed tomography demonstrated fracture lines were not seen due to overlying callus on plain films and also more accurately showed incomplete union. By 36 weeks, healing was essentially complete according to both modalities, although there still were small gaps in the callus detectable on computed tomography however not on plain films. Computed tomography might be of value in the evaluation of fractures of long bones in those cases in which clinical examination and plain radiographs fail to give adequate information of the status of healing.

Orosz and Toal (1992) opined that the birds must be anesthetized during computed tomography examinations to avoid movement and stress.

Raiti and Haramati (1997) reported that all calcified structures were depicted easily in computed tomography studies in gravid leopard tortoise.

Gumpenberger and Henninger (2001) opined that computed tomography studies were radiography-based thin cross-sectional scans that allowed non-invasive imaging without disturbing superimposed structures and advantages for detection of pathologies in birds. The scans were usually done in transverse direction, with 1 mm to 5 mm slice thickness. Computer programs were able to build three dimensional models of these slices. They reported that in birds, the radiographic examination of the skull and appendicular skeleton usually provided sufficient information. However computed tomography studies showed more details that might be overlapped by soft tissues, wings, or legs. They also reported a healed fracture in common kestrel using computed tomography by taking sagittal scan of right tibiotarsus. They reported that three dimensional reconstructions of

bony lesions also gave additional information to surgeons. It also helped to improve knowledge of rare uncommon species.

Helmer (2006) opined that cross sectional image eliminates overlying structures so objects of interest were more accurately visualised. Computed tomography was best suited for evaluation of bone and air-filled structures.

Gumpenberger and Scope (2012) reported that computed tomography in conscious wild birds was less stressful than the manipulations associated with the taking of radiographs.

Grosso (2019) opined that computed tomography had many advantages compared with radiography. The major advantage over radiography was the ability to visualize the internal anatomy without superimposition of the adjacent or external structures. Computed tomography had a higher contrast resolution than radiography, thus distinguishing between different types of soft tissues and fluids. In addition, the great spatial resolution of computed tomography could help to detect subtle fractures that might not be seen with other imaging modalities. Multiplanar reconstructions (dorsal and sagittal) could be reformatted after acquiring the transverse scan of the patient. Multiplanar reconstructions allow the clinician to appreciate the disease, because it was oriented relative to the surrounding anatomy. Three-dimensional renderings could also be performed. Reconstructions could be very helpful for surgical planning, especially in complicated fracture.

Huynh *et al*. (2019) reported that deformities of skull bone segment and complex fractures were best visualised with computed scan and three-dimensional reconstruction.

Nicholson *et al*. (2021) opined that computed tomography scanning had become increasingly popular and could evaluate bridging callus in the late stages of healing to confirm union. Computed tomography scanning was a useful investigation to confirm union in long bone fractures when there was a doubt with radiographs. Additionally, evaluation of callus formation for evidence of early bridging might be of use in the recovery phase.

2.8 PRE-OPERATIVE PREPARATION

2.8.1 Patient stabilization

Bush (1977) suggested dexamethasone sodium phosphate at 0.5 mg/kg intravenously and lactated ringers' solution was given for stabilization of red-tailed hawk.

Bennett and Kuzma (1992) opined that vomiting and regurgitation may occur if the patient is not fasted and can result in aspiration pneumonia. A short fast of 1-3 hours decreases the probability of aspiration pneumonia and minimal effects on blood glucose values intra-operatively. Oral 5 % dextrose may be administration intravenously to maintain the patient's blood glucose. They suggested that fracture assessment and repair should be postponed until the patient is stable and life-threatening problems solved. The initial examination should be as atraumatic as possible and should include haemostasis, shock therapy and temporary support for any fractures.

Kavanagh (1997) suggested that bubble wrap was used to insulate the bird to reduce the heat loss from the bird.

Forbes (1998) reported that small birds (less than 200g) also require fasting. The fasting interval is calculated as the time from food removal to eating post-operatively and should not exceed 3 hours. Waterfowl and carnivores should be fasted for 4 to 10 hours depending on size of the species. Birds should not be anesthetised with a full crop. He also suggested sick birds should be medically stabilised, using fluids, antibiotics and food. If the packed cell volume was below 20% there would be either severe anaemia or haemodilution present and surgery should be delayed, if possible. If the packed cell volume was greater than 55 %, then severe dehydration would be present and rehydration should be carried out prior to surgery. Wherever possible, evidence of liver or kidney impairment should be ruled out. Birds with impaired kidney function should not receive ketamine as the drug would be excreted via this route. Birds must be weighed prior to an injectable anaesthetic being administered.

Hollamby *et al.* (2004) opined that pre-operative bacterial culture from fracture site was essential to choose suitable antimicrobial agent.

Davidson *et al.* (2005) stated that a recirculating water heating pad was used for maintaining body heat of the bird for surgical correction of the fractured coracoid with an implant.

Gayathri and Sunil (2018) suggested that emergency treatment of shock, haemorrhage and sepsis must be given first. It was important to assess the patient

holistically, including diet, husbandry and concurrent medical conditions, without focusing solely on the obvious injuries.

2.8.2 Surgical site preparation

Bennett and Kuzma (1992) suggested that patient preparation with excessive amounts of water or alcohol could predispose the patient to hypothermia.

Kavanagh (1997) opined that a minimal number of feathers were plucked at the surgical site to reduce body heat loss. The surgical area was scrubbed with chlorhexidine gluconate in warm water to avoid excessive wetting of the feathers.

Nanjappa *et al.* (2013) reported that the bird was restrained in left lateral recumbency and the surgical site was prepared for aseptic surgery by plucking the feathers. The wounded site was flushed with lukewarm normal saline mixed with 1% chlorhexidine solution and the adjoining feathers were plucked off around the injury site to prevent further wound infection. The wound was then thoroughly debrided followed by topical application of 5 % povidone-iodine solution.

Gayathri and Sunil (2018) suggested that as a part of the pre-operative measures, the feathers in the area of the fracture was clipped, scrubbed and bandaged. Prior to the surgery the area was aseptically sterilized and an antibiotic was given parenterally.

2.8.3 Endotracheal intubation

Hartsfield and McGrath (1986) opined that in poultry there were no unusual anatomic characteristics that limit intubation in anesthetized patients. The glottis is located

on the midline in the caudal portion of the tongue. In lightly anesthetized birds, the anterior larynx was responsive to stimuli and might hamper tube placement. In chickens, the female was more easily intubated than the male because the glottis was more visible. Because the avian trachea is composed of complete rings, special care should be taken to use correctly sized endotracheal tubes and to avoid excessive inflation of the endotracheal tube cuff. Overinflation of the cuff might damage the tracheal mucosa and rings. When cuffed tubes were chosen, Murphy tubes with an end hole and a side hole were the tubes of choice.

Curro (1998) opined that endotracheal intubation provided airway access for the delivery of oxygen and anaesthetic gases and an effective route for delivery of manual or mechanical ventilation. The endotracheal tube protected the airway from aspiration of secretions and refluxed gastrointestinal contents. For an endotracheal tube to perform these functions properly, a sealed airway was required, which could not be achieved with either an uncuffed or an uninflated cuffed tube. Endotracheal intubation with cuffed tubes was recommended for use in birds despite the presence of complete cartilaginous tracheal rings in all species. The cuff was carefully inflated just enough to prevent leakage when 10 to 15 cm H_20 pressure was applied to the airway. The size of the bird would dictate the size of endotracheal tube used. The smallest available cuffed tubes had an internal diameter (ID) of 3.0 mm. Psittaciformes as small as 350 g had been intubated with a 3.0 internal diameter tube. Birds smaller than this required the use of uncuffed tubes or large gauge IV catheters. Birds as small as 100 g might be intubated with these smaller tubes. Care was taken when catheter-sized tubes were used, because they would not provide a sealed airway and might easily become plugged with secretions, mucus, or blood. Also, the resistance to gas flow through small catheters was high, which might significantly impede both spontaneous and

manual ventilation. Use of Murphy tubes, which had a side opening as well as an end opening, decreased the chance of mucus occlusion. Airway patency was checked regularly during general anaesthesia. Birds smaller than 100 g were best maintained with a mask.

Brown and Pilny (2006) suggested that endotracheal intubation was easy to perform in birds, it was non-invasive and it allowed accurate ventilation monitoring. Air sac perfusion or air sac cannulation anaesthesia was used when intubation was not possible or contraindicated, in emergency cases.

Guzman *et al.* (2007) reported intubation with a 5.0-mm uncuffed endotracheal tube in an adult bald eagle for repair of coracoid luxation.

Lichtenberger and Ko (2007) opined that most birds weighing 100 g or more could be intubated with minimal difficulty. It was possible to intubate birds as small as 30 g in body weight, but they presented a greater challenge because of the small tube size. For small birds, an endotracheal tube could be made using a red rubber tube or catheter of the appropriate size. Small birds produced mucous that clogged these small diameter tubes. Clogged tube caused hypoventilation and hypercapnia. Frequent suction might be required during anaesthesia to maintain the patency of the tube.

Hoybergs *et al.* (2008) reported that an uninflated 3mm endotracheal tube was used in a 2-year-old captive bred female Harri's hawk for surgical repair of tarsometatarsus fracture. If food status was unknown and surgery was required, intubation and inclining the body to a more upward position were logical precautions to prevent regurgitation.

Al-Sobayil *et al.* (2009) reported that 14 mm cuffed endotracheal tubes were used. Intubation of the birds was very easy, with no need for a laryngoscope or a guide tube. The beak was opened, and the glottis was easily identified at the base of the tongue. Because the trachea of the ostrich was composed of complete cartilaginous rings, the cuff of the endotracheal tube was inflated by injecting small amounts of air (5–10 mL) into the cuff to prevent trauma to the trachea. This amount of air created an internal pressure on the trachea that was enough to prevent leakage of anaesthetic gases into the environment and at the same time did not interfere with tracheal mucosal blood flow.

Stejskal *et al.* (2011) reported that a 3.5 mm endotracheal cuffless tube was used in black swan.

2.9 ANAESTHETIC PROTOCOL

2.9.1 Anaesthetic agents

Fedde (1978) reported that ketamine had a wide margin of safety, even in birds. It produced a rapid induction (immediately if administered intravenously and 1 to 5 min if administered intramuscularly) and recovery at appropriate doses. The duration of immobilization varied with the dose (20 to 30 minutes) and prolonged recovery occurred at higher doses (90 minutes) or with repeated administrations.

Degernes *et al.* (1988) reported that a dose of 4.4 mg/kg ketamine and 2.2 mg/kg xylazine provided adequate short-term anaesthesia for red-tailed hawks.

Bennett (1993) reported that ketamine combined with xylazine was a commonly reported injectable regimen for birds.

Krajca and Juranova (1994) reported that the xylazine-ketamine cocktail gave a very fast and smooth induction of anaesthesia associated with deep analgesia, good muscle relaxation, and absence of all reflexes.

Lukasik *et al*. (1997) reported that propofol used for induction and maintenance in chickens was associated with significant adverse cardiopulmonary effects and could not be recommended for use in pet birds.

Curro (1998) reported that benzodiazepines were recommended as they produce minimal adverse cardiopulmonary effects. A tiletamine (dissociative) and zolazepam (benzodiazepine) combination, provided effects similar to ketamine and diazepam, with a longer duration of effect. He also reported that xylazine improved anaesthetic recovery and provided sedation and analgesia when used in combination with ketamine. Unfortunately, xylazine had potent cardiopulmonary-depressive effects, which were not compensated by the effects of ketamine. Ketamine alone usually produced inadequate anaesthesia and recoveries were often violent.

Forbes (1998) opined that ketamine was administered in combination with diazepam, midazolam, xylazine and medetomidine. Medetomidine administered at 150 to 350 μg/kg and ketamine at 4 to 10 mg/kg intramuscularly, accomplished good surgical anaesthesia of approximately 30 minutes duration. Anaesthesia was rapidly and totally reversed by the same volume of atipamazole. Analgesia following reversal was poor. He also opined that an alphaxalone-alphadolone combination was well tolerated by many species, however, could lead to adverse reactions in some species such as red-tailed hawks and certain psittacines.

Green *et al.* (1981) opined that in domestic fowl ketamine alone was injected into the pectoral muscles at doses of 15 to 60 mg/kg. The time taken for onset of sedation when the birds keeled over to lay on their side was 2 minutes, peak effect was maintained for 30 to 50 minutes. When the birds were given ketamine at 25 mg/kg intramuscularly concurrently with diazepam at 2 to 5 mg/kg intramuscularly or with metomidate at 5 mg/kg, they were relaxed and analgesia was good, even though some of them remained awake and aware of their surroundings.

Abou-Madi (2001) opined that ketamine caused variable effects in many species such as great homed and snowy owls, Cooper's and sharp-shinned hawks, and waterfowl failed to produce general anaesthesia.

Vesal and Eskandari (2006) reported that combinations of midazolam 3.65 mg/kg and xylazine 10 mg/kg with ketamine 40 to 50 mg/kg produced adequate sedation.

Lichtenberger and Ko (2007) reported that sevoflurane in birds seemed to be less irritating and thus reduced the stress of mask inhalation. They opined that all inhalants produced dose-dependent decreases in cardiac performance. Halothane showed dose-related decreased cardiac output, blood pressure and systemic vascular tone, whereas isoflurane preserved cardiac output, however, it altered systemic vascular tone and tissue perfusion.

Durrani *et al.* (2009) reported that for handling and less painful procedures in pigeons, xylazine (alone) could be used effectively and safely, while for painful procedures the use of a xylazine-ketamine cocktail was more appropriate. Ketamine (alone) produced

undesirable anaesthesia for pigeons during recovery phase and was also associated with hyperthermia.

Mostachio *et al.* (2008) reported that xylazine administered at the rate of 3 mg/kg intramuscularly followed by induction of anaesthesia 15 minutes later with diazepam at 4 mg/kg intramuscularly and ketamine at 25 mg/kg intramuscularly provided a smooth induction, a moderate duration of anaesthesia and good recoveries in birds. The combination at the doses used would not be ideal for short procedures where a rapid recovery is desired.

Al-Sobayil *et al.* (2009) opined that induction of anaesthesia with xylazine-ketamine followed by maintenance with isoflurane produced sufficient anaesthesia for performing surgical operations with relatively smooth recovery in adult ostriches.

Lierz and Korbel (2012) reported that insufficient analgesic potency and poor muscle relaxation under ketamine anaesthesia and recovery was excitable. Therefore, ketamine should not be used as a single anaesthetic agent. However, might be used in combination with an alpha-2-agonist or a benzodiazepine drug. They also suggested that local anaesthesia was not commonly used in avian patients because small doses of local anaesthetic drugs produced toxic effects and most importantly, the patient remained conscious during a very stressful procedure.

Kamiloglu *et al.* (2014) concluded that if a quick and convenient way of anaesthesia for urgent operation was desired, intraosseous route could be used as an alternative way.

Moreover, using the ketamine-xylazine combination was considered as a viable choice that resulted in sufficient and appropriate anaesthesia in quails.

Mahmud *et al.* (2014) reported that in cockerel chickens, diazepam alone could be used for less painful surgical procedures and handling. However, in the cases of more painful surgical procedures that may take quite a long time, use of ketamine-diazepam combination dosed at 10 mg/kg and 2 mg/kg intramuscularly respectively, was safer and strongly recommended.

Alatroshi and Naser (2021) opined that alfaxalone produced light surgical anaesthesia so that it can be mixed with ketamine or xylazine for deep surgical anaesthesia.

2.9.2 Anaesthesia monitoring

Curro (1998) opined that respiratory rate was usually rapid and irregular with a shallow tidal volume during initial stages of induction, but became slow, regular, and deep as a medium surgical plane was achieved. Respiratory rate and tidal volume continued to decrease as anaesthetic depth increases. Visual monitoring of the bird and the rebreathing bag would allow assessment of respiratory rate and provided crude evaluation of tidal volume. Heart rate and rhythm were monitored. Direct auscultation with a stethoscope was useful, however, this may be difficult in small birds under surgical drapes. Pulse oximeters were becoming a popular monitoring tool in veterinary medicine. These devices provided an indirect measure of haemoglobin saturation with oxygen. Pulse oximeters were useful evaluators of changes in pulse rate and percentage of oxygen saturation. Reflectance probes had been successfully used orally and cloacally.

Abou-Madi (2001) opined that in birds the respiration was assessed visually, with measurement of the respiratory rate, the depth of each breath (amplitude of movement of sternum), and tidal volume. Bag movements gave an erroneous appreciation of respiration. Noisy breathing indicated possible obstructed breathing and upper airway obstruction. Any obstruction was be cleared immediately.

Durrani *et al.* (2009) reported that in birds treated with xylazine, all reflexes were present, except feather plucking reflex. In ketamine treated birds only righting reflex, feather plucking reflex and table knock reflex were absent, while in xylazine-ketamine treated birds there was a complete absence of all reflexes. He also reported that in ketamine treated birds there was a slow but smooth induction of anaesthesia. Ketamine induced a very light anaesthesia with poor muscle relaxation, superficial analgesia and absence of all reflexes except palpebral reflex and pharyngeal reflex.

Hoybergs *et al.* (2008) opined that breathing quality, corneal reflex, feather plucking response and toe pinch reflex were used as a tool to access anaesthetic depth during orthopaedic repair in Harris's hawk.

Mostachio *et al.* (2008) reported that intramuscular injection of xylazine at 3 mg/ kg smoothly induced loss of the righting reflex within 3 to 4 minutes. He also reported that roosters anaesthetized with xylazine at 3 mg/ kg, diazepam at 4 mg/kg and ketamine at 25 mg/kg. This combination showed a significant decrease in heart rate, respiratory rates and cloacal temperature. The recovery period lasted for up to 4 hours.

Lierz and Korbel (2012) reported that ketamine alone did not result in muscle relaxation and the bird could become very excited during recovery. Anaesthesia in birds was closely monitored until all reflexes returned and they were able to perch as normal. For recovery, a quiet, warm and light-reduced environment was selected; which allowed for visual control of the patient. Patients were immediately placed in ventral recumbency and loosely wrapped in a towel to avoid wing flapping. Wing flapping typically occurred when using injectable anaesthetic agents like ketamine. The towel was removed as soon as the bird was lifting its head and opened its eyes with a concurrent recurring pedal reflex. Water was only offered when the bird had regained full consciousness. The endotracheal tube was removed when the bird demonstrated spontaneous breathing, general muscle tone and the ability to move its head.

Kamiloglu *et al.* (2014) stated that superficial (needle used to prick the skin) and deep pin-prick (needle inserted into the muscle) were performed on different body parts to access the depth of anaesthesia. Other body reflexes (righting reflex, feather plucking reflex, palpebral reflex, pharyngeal reflex) were recorded during xylazine-ketamine anaesthesia in quails.

2.10 SURGICAL TREATMENT FOR TIBIOTARSUS FRACTURE REPAIR

2.10.1 Conservative treatment

2.10.1.1 Cage rest

Levitt (1989) suggested that minimally displaced and greenstick fractures healed well by restricting the bird's activity using cage confinement.

Bennett and Kuzma (1992) suggested that few fractures in birds healed adequately with no form of fixation. The bird was maintained in a small cage and kept as quiet as possible. The photoperiod might be adjusted to keep the patient inactive. The cage was small enough to prevent excessive motion such as wing flapping or walking around. Cage rest as a method of fracture management was inexpensive and easily accomplished. The joints of the affected limb were unrestricted so ankylosis resulting from joint immobilization was unlikely to occur. However, excited birds with fractures left unstabilized might traumatize or mutilate themselves.

Scheelings (2014) suggested that cage rest without surgery appeared prudent when managing coracoid injuries in birds.

Carrasco *et al.* (2018) opined that cage rest was also suitable for patients who were not suitable candidates for external coaptation or surgical repair, such as very small birds or those with pelvic fractures.

Cracknell *et al.* (2018) suggested that conservative management of closed coracoid fractures in birds without significant wing droop, with cage rest and analgesia, appeared to yield a good success rate, irrespective of fracture severity and was recommended as the first line treatment of choice for the majority of cases.

2.10.2 External coaptation

MacCoy (1992) reported that tibiotarsus fractures were immobilised by modified Robert Jones bandage. A splint was incorporated in the outer layer of the bandage. Fiberglass, wood, or split plastic tubing also worked well. The one difficulty encountered

was including the stifle joint in the bandage to provide good rotational stability to the fragments. In long-legged birds, this was not a problem. In short-legged birds, such as the psittacines, the stifle was adjacent to the flank, thus preventing incorporation in a bandage. Modified Thomas splints might also be used for fractures of this bone, especially in large species. Care must be taken to prevent pressure sores where the splint contacts the abdomen.

Rupiper (1993) reported that the visible light curing composite splint had been successfully used on birds that range in size from a finch to an African Grey Parrot without the application of an Elizabethan collar. It provided an excellent alternative to tape splints and casting materials for external coaptation of appropriate fractures in birds.

Jalila *et al.* (2009) reported that an adult Hill Mynah with distal transverse fracture of the left tarsometatarsus was treated using a combination of external coaptation using tape splint and ball bandage. It was found that this combination technique resulted in a clinical union of the fractured site at three weeks post-treatment. This technique also provided perching and movement stability in the cage.

Javdani and Nikousefat (2012) reported that a 10-month-old male sparrowhawk with an open antebrachium fracture was treated using external coaptation using splint and bandage. Post-operative monitoring of the patient by clinical and radiographic examination showed repair of the fracture within 7 weeks and the bird was able to fly.

Beaufrère *et al.* (2012) reported that a figure-of-eight bandage was initially applied to the wing to stabilize the ulnar fracture. Over a 5-week period, the kite developed

progressive reduction in wing extension and serial radiographs revealed a bridging callus at the ulnar fracture site, as well as development of a radioulnar synostosis.

Carrasco *et al.* (2018) suggested that Altmann's tape splint was indicated for long bone fractures of the hindlimb where the joint above and below could be included. This technique could also be attempted in very distal femoral fractures in small birds. Aluminium foam-backed splint had a 2 mm thick aluminium base, covered with a padding of foam along one side. They were lightweight and flexible, and could be shaped to fit each case. This splint foam could be used to temporarily treat tibiotarsus fractures, the splint was placed cranially and caudally and was shaped to fit and immobilise the proximal (knee) and distal (tibiotarsus-tarsometatarsus joint) joints. This technique was used in bigger birds where the Altmann's tape splint would not provide enough stability. Ideally, the splint should have been placed both cranially and caudally. Syringe barrel splint could be used for long bone fractures such as those of the tibiotarsus and tarsometatarsus. The syringe to be used varied depending on the size of the affected bone. Both ends of the syringe barrel were cut off, then the syringe barrel was cut longitudinally. A layer of conforming stretch bandage was placed over the affected limb. The syringe barrel was placed over the fractured bone and secured proximally and distally with tape in a sandwich fashion.

Wright *et al.* (2018) suggested that a tape splint was an appropriate means for treatment of tibiotarsus fractures in birds weighing less than 200 g.

2.10.3 External skeletal fixation

Kavanagh (1997) concluded that the external skeletal fixator was ideal as it addressed all the destabilising forces, preserved the intramedullary blood supply, avoided

soft tissue damage close to the fracture site and was robust enough to survive on the bird's leg. Early limb use was possible, which helped to maintain muscle tone and joint movement. The incidence of fracture disease was reduced. Additionally, it allowed the fracture callus to be progressively loaded by staged removal and it was cheap and relatively quick to apply and remove.

Lewis *et al.* (1998) suggested that combining a linear external fixator with a circular external fixator employed the best features of each method while limiting the disadvantages of each.

Rochat *et al.* (2005) reported that an open-wedge corrective osteotomy was performed and a Type IA hybrid external skeletal fixator was used to stabilize the osteotomy in an eagle. The osteotomy healed and the eagle was returned successfully to the wild.

Redig (2005) opined that 50 to 65 per cent of the marrow cavity was filled by intramedullary pin used for tie-in fixation.

Hoybergs *et al.* (2008) reported that type IIA external skeletal fixator was used for surgical repair of a tarsometatarsus fracture in a Harris's hawk. Post-operative radiographs revealed good alignment, good reduction (over 90% bone to bone contact) and correct pin placement. Six weeks after surgery, radiography was performed to assess fracture healing. The radiographs showed a good fracture healing with medium graded osteolysis around the distal pin and low graded osteolysis around the proximal pin. It was concluded that fracture healing was sufficient enough to remove the external skeletal fixation.

Johnston *et al.* (2008) reported that after intramedullary pin and external coaptation with a modified Robert-Jones bandage a tibiotarsus fracture failed to heal, the parrot was fitted with a ring fixator device and bone transport osteogenesis was attempted. Within 7 weeks, the left tibiotarsus had regrown to full length, but the docking site at the proximal fracture line had not healed. After 2 more surgeries to debride bone ends to stimulate healing, the leg in this parrot became functional.

Van Wettere *et al.* (2009) reported that by using the tie-in configuration, increasing the diameter of the acrylic connecting bar, and increasing the diameter or number of fixation pins, each significantly increased the stiffness in all assessments. Placing the fixation pin distally in the proximal bone model segment increased the stiffness in bending, and adding a fixation pin to the distal bone model segment increased the stiffness in torque and bending. These results quantified the relative importance of specific parameters that affect stiffness and safe load of the ESF-IM tie-in construct as applied to a plastic bone fracture model.

Ferraz *et al.* (2010) concluded that hinged linear external fixation could be used with a positive outcome, in specific cases, for the treatment of tibiotarsus – tarsometatarsus limb deformity and gastrocnemius tendon dislocation in young birds, and was a good alternative to bandaging or surgically ankylosing the tibiotarsus joint.

Kubiak and Forbes (2011) opined that tie in fixation involved making a surgical incision on the medial aspect of the leg, over the fracture site, and inserting an intramedullary pin retrograde into the proximal fragment with the stifle flexed and passing normograde into the distal fragment. The proximal pin end was then be bent at 90°, 5 mm

from the exit point, and directed laterally, after which threaded external skeletal fixator (ESF) pins could be placed lateral to medial in the proximal and distal fragments through both cortices. ESF and intramedullary pins were joined with a straight bar, restrained with cerclage wires and overlaid with methyl methacrylate to secure the fixator.

Tunio *et al.* (2014) concluded that fracture of a pigeon ulna fixed with external skeletal fixation provided excellent fracture healing and good clinical union. External skeletal fixation was a safe and suitable method used in fracture fixation in birds. It was concluded that external skeletal fixation might accelerate fracture healing and could be convenient for fracture fixation in birds for clinical fracture management.

Bueno *et al.* (2015) opined that the tie-in fixator (TIF) was generally well tolerated by raptors. The design of the TIF was inherently resistant to any efforts a bird might make to dismantle or remove it. This is in contrast to an intramedullary pin alone, which could be dislodged rather easily. Moreover, in the few instances in which elements of the TIF had to be prematurely removed, the fractures typically continued to heal.

Carrasco *et al.* (2018) reported that a tie-in fixator allowed use of the joints and were preferable to other treatment options such as external coaptation, which kept the joints immobilised for the whole healing period.

Ozsemir and Altunatmaz (2021) opined that a modified Meynard external fixator, which was made applicable for fractures in birds, could be an alternative method for fracture treatments in wild birds.

2.10.4 Internal fixation

MacCoy (1987) suggested that open reduction had to be done for internal fixation in birds weighing more than 400 g.

2.10.4.1 Intramedullary pinning

Bush (1977) reported that fracture fixation with intramedullary pins in birds had disadvantages if pinning was retrograde. The fracture site was invaded surgically, which further disrupted blood supply to the fractured segment. In pneumatic bones, the medullary space was extremely large, requiring one large pin or several small pins which might lead to excessive weight of the fixation. Rotation of the pin was due to inability of the pin to fill the medullary cavity due to lack of dense bone. Intramedullary fixation prevented or disrupted callus formation.

Westfall and Egger (1979) opined that Steinman pins which were slightly tight in the marrow cavity. The thin cortices of the avian bone tended to fissure fracture quite readily. If this was the case, a slightly smaller pin was used in conjunction with devices to prevent rotation. Cerclage wires could easily be applied to prevent the fissure fractures from extending. Finally, pins tended to extend into joints and resulted in stiffness which severely limited the ability of the bird to perform.

Bennet and Kuzma (1992) opined that the weight of steel intramedullary pins generally represented a much higher percentage of body weight in birds than in most mammals and if not removed, these pins prevented flight. In most instances, Steinmann pins could be removed without general anaesthesia.

Wan *et al.* (1994) concluded that use of polydioxanone pins provided adequate stability for the repair of simple humeral fractures in avian species. The use of external coaptation was deemed necessary initially due to post-operative instability, whereas a second surgery to remove the pins was not necessary. Callus formation was similar to that observed when stainless steel intramedullary pins were used for fracture stabilization.

Harcourt-Brown (2002) reported that fracture fixation using intramedullary, trocar-pointed, 0.8 mm to 2.0 mm Steinmann pin was a reliable repair method. For this method to work, the pins had to stabilize the bone. If the bone had a large medullary cavity and a single pin was not sufficient to fill the medullary cavity; stack pinning might be necessary to reduce the likelihood of longitudinal rotation. After fracture repair using an intramedullary pin, the bone was checked for possible longitudinal rotation. If present, the rotation was stabilized by an external splint. He also suggested that small birds might have their long bones pinned with reusable hypodermic needles or with the stylets from spinal needles. If possible, all pins should be removed after bony union. Pin exposure should be reduced, because the patient may remove any pins that protrude through the skin.

Dias (2018) concluded that polyamide 12 intramedullary rod was biocompatible and provided adequate bone consolidation in humeral fractures with no signs of rejection.

Gayathri and Sunil (2018) reported using 3 mm Steinman pin in a diaphyseal humerus fracture in a Pariah Kite was corrected and recovery was observed in one month.

Suryawanshi *et al.* (2021) reported that an intramedullary pin, measuring 0.5 mm thickness was inserted into the marrow by retrograde method and the fractured fragments

were reduced near to anatomical position without ankylosing proximal and distal joint. Post-operatively, the operated limb was supported with additional splint bandage to immobilize the fractured fragments. The bird started bearing weight on the fractured limb on the 10th day. The bird was evaluated radiographically on the 21st day which revealed formation of healthy callus at the proximal diaphyseal transverse fracture site and the bird was sheltered in a flight cage for 15 days. Intramedullary pin was removed uneventfully after seven weeks following radiographic confirmation of hard callus.

2.10.4.2 Cerclage, hemi cerclage and interfragmentary wiring

Bennett and Kuzma (1992) opined that orthopaedic wires (cerclage, hemi-cerclage, and interfragmentary) were frequently used in avian fracture management as an adjunct to intramedullary pin stabilization.

Harcourt-Brown (2002) opined that cerclage wires were useful to keep the bone from splitting if there was a crack in the cortex or to reposition a large fragment. The wire was placed loosely around the split area of the shaft before reducing the fracture to avoid trapping a nerve. In large birds, a hemi-cerclage technique using 22G orthopaedic cerclage wire could be used to overcome the problem of placing a small-diameter pin in a large medullary cavity. Pins and a compression wire could be used to repair fractures of long bone extremities.

2.10.4.3 Intramedullary interlocking nail

Hollamby *et al.* (2004) reported that a transverse, midshaft, comminuted left tibiotarsus fracture of a bald eagle was reduced and fixation established with a 4.7 mm

diameter, 112 mm long, four-hole veterinary intramedullary interlocking nail maintained in position by a single 2 mm transcortical screw placed in the main proximal and distal fragments. The bird was weight bearing on the bandaged limb 48 hours post-operatively. Radiographs obtained 4 weeks post-operatively revealed bridging callus over three of four cortices. The bird was released back into wild. He also opined that the main function of the screws in interlocking nailing was to prevent rotation, compression or torsion.

Stejskal *et al.* (2011) reported that in comparison to intramedullary pinning, bone plates, external skeletal fixation, intramedullary interlocking nail method of fixation was biomechanically beneficial for tibiotarsus fracture in birds. They also reported that intramedullary nailing provided stability at the fracture site in terms of rotation and compression, thus avoided the joint penetration hazard at the same time.

2.10.4.4 Bone plating

Bush *et al.* (1976) opined that plate fixation for fractures in birds had historically been discouraged because the thin cortices of avian bones were unable to provide adequate screw purchase. However, plates were successfully used for fracture management and corrective osteotomies in large birds whose bones had substantial cortical thickness, such as the legs of ratites. The equipment was expensive, the surgical exposure and tissue dissection was extensive and the surgery time was prolonged.

Newton and Zeitlin (1977) opined that in the absence of rigid stability, both mammalian and avian fractures healed by secondary bone healing with callus formation. Fractures with greater stability had less callus formation. Stable fractures appeared to heal

more rapidly in birds than in mammals. In uncomplicated cases, bone healing in small birds was usually completed by 3–6 weeks.

Kuzma and Hunter (1989) opined those fractures might result at the ends of the plate where the bone had been stressed protected. Due to these factors, plate removal prior to release of wild birds was recommended.

Howard (1990) opined that bone plates provided the advantages of rigid internal fixation and an anatomic alignment without interfering with joint function, thus allowed early return to function.

Bennett and Kuzma (1992) opined those fractures repaired using bone plates might heal by primary bone healing with minimal or no callus. They also reported the usage of dynamic compression plates and veterinary cuttable plates in birds with success.

Tepic and Perren (1995) opined those plates with limited or pointed contact with the bone were designed to reduce compression of the periosteum and vascular damage to the plated bone segment.

Herford and Ellis (1998) reported that the advantage of locking bone plate/screw systems was that screws were unlikely to loosen from the bone plate. This meant that even if a screw was inserted into a fracture gap, loosening of the screw would not occur. Similarly, if a bone graft was screwed to the plate, a locking screw would not loosen during the phase of graft incorporation and healing. The possible advantage to this property of a locking plate/screw system was a decreased incidence of inflammatory complications from loosening of the hardware in humans.

Davidson *et al.* (2005) suggested that the most appropriate size seemed to be the 2.0 mm plate for coracoid fracture repair in a bald eagle. Although a 2.7 mm plate might have fit the bone. For the thin cortices, smaller threads of the 2.0 mm screws were more appropriate.

Guzman *et al.* (2007) reported a luxation affecting the coracoid-sternum articulation in bald eagle was repaired by using a 4-hole, 1.5 mm T-plate and a 6-hole, 2.0 mm dynamic compression plate placed side by side. In the same bird a closed, complete mid diaphyseal transverse fracture of the right tibiotarsus, which most likely occurred during recapture from the flight cage. The fracture was surgically repaired with 2 circumferential cerclage wires, an intramedullary Kirschner wire and one 10-hole, 2.7-mm dynamic compression plate.

Hatt (2008) opined that bone plates provided stability against shear forces and rotation. In comparison to intramedullary pin, external skeletal fixators, bone plates were internal; therefore, they were less likely to be destroyed by the bird or to become entangled.

Langley-Hobbs *et al.* (2009) opined those screws should be at least as long as the measured depth or 2 mm longer than the measured length to ensure that the threads on the screw adequately engaged the trans-cortex and 2 screws on each bone fragment were used to prevent plate loosening in cats.

Gull *et al.* (2012) reported that three different miniplate systems were used in avian fracture repair in 18 pigeons. In group A (n=6), a 1.3 mm adaption plate was used. In group B (n=6), a limited contact system was created with washers that were placed between the

bone and a 1.3 mm adaption plate. In group C (n=6), a 1.0 mm maxillofacial miniplate was used. Birds in group A with the adaptation plate achieved the best flight results (100%). In group B birds, no effect of the limited contact concept was visible at necropsy and a high percentage of the screws had loosened, leading to failure (33%). The maxillofacial miniplates of group C birds were too weak and bent (100%). In tibiotarsus fracture Plates were fixed on the medial side of tibio-tarsus and all the screws were placed bicortically.

Bennert *et al.* (2016) evaluated two different miniplate systems and figure-of-eight bandages for experimental study of ulnar and radius fractures in 27 pigeons. In group-I and II (n=14) a 1.3 mm adaption plate was applied without and with figure-of-eight bandages. In group-III and IV (n=13) a 1.0 mm compression plate was applied without and with figure-of-eight bandages. Radiographic healing was evaluated after 3, 14 and 28 days. They concluded that 23 birds showed 85.20 % success. They recommended that 1.3 mm adaption plate and 1.0 mm compression plate met the desired requirement for fracture stabilization.

2.11 IMPLANTS

2.11.1 Reconstructive plates

Ost and Kaderly (1986) suggested that reconstruction plates could be contoured in three planes, whereas conventional plates could be contoured only in two planes. Bending in the third dimension was made possible by notches in the plate between each screw hole. Pre-contouring before surgery decreased intra-operative time and corrected minor discrepancies in reduction. Excellent anatomical reduction of acetabulum and ilial fractures was achieved.

Onodera *et al.* (1993) reported that a 41-year-old man had been treated for ameloblastoma by partial resection of the mandible followed by reconstruction with the use of a titanium plate to bridge the mandibular defect. Titanium pigmentation occurred in the surrounding soft tissue adjacent to the plate and within a submandibular lymph node 2 years after reconstruction.

Herford and Ellis (1998) opined that the advantage of locking reconstruction bone plate/screw systems was that the screws were unlikely to loosen from the bone plate. This meant that even if a screw was inserted into a fracture gap, loosening of the screw would not occur. Similarly, if a bone graft was screwed to the plate, a locking screw would not loosen during the phase of graft incorporation and healing. The possible advantage was a decreased incidence of inflammatory complications from loosening of the implant. He also opined that locking reconstruction plate offers advantages over conventional bone plates by not requiring the plate to be compressed to the bone to provide stability.

Conzemius and Swainson (1999) reported that reconstructive plates worked well in areas where plate contouring could be difficult and the oval screw holes increased the versatility of the angle at which screws could be placed, however, they were less resistant to bending forces.

Ellis and Graham (2002) opined that the most significant advantage of locking reconstruction plates might be that it becomes unnecessary for the plate to have intimate contact with the underlying bone in all areas. As the screws were tightened, they lock to the plate, thus stabilizing the segments without the need to compress the bone to the plate.

Kirkpatrick *et al.* (2003) concluded that the use of locking reconstruction plates can facilitate the management of complicated fractures; however, it did not eliminate complications. A minimum of 3 screws per side should be used in all fractures requiring the use of locking reconstruction plates.

Boudrieau *et al.* (2004) reported that mandibular reconstruction plate and locking mandibular reconstruction plate were secured to the ventral borders of the mandibles and used as buttress plates successfully for mandibular fracture with minor complications.

Knot *et al.* (2007) reported that locking mandibular reconstruction plate was used for mandible reconstruction using vascularized bone grafts. This latest-generation system eliminated plate fracture, minimized screw loosening and non-union. That remained a 15% incidence of hardware related complications, most often related to hardware extrusion. This complication was effectively managed by hardware removal.

Coletti *et al.* (2009) stated that initial reconstructive plates (bridging plates) were non-locking in nature and created an environment for potential failure. When non-locking screws were tightened, pressure was translated through the plate to the underlying bone. This occurred over a period of time and led to bone resorption beneath the plate, resulting in loosening of the plate. Locking technology alleviated this by using the benefits of an external fixator to an internal plate. The locking plate was united to the screw through a second set of threads within the head of the screw. As the surgeon completes the tightening, the screw ‘locked’ itself to the plate and created a single functional unit and minimized the transmission of pressure to the underlying bone.

Elsalanty *et al.* (2009) reported the successful use of bone transport reconstruction plate where there was a 3 cm defect in one side of the mandible.

Robertson *et al.* (2009) reported that locking reconstructive plates were significantly stiffer than the non-locking reconstructive plates.

Cho *et al.* (2010) observed that the reconstructive plate could be contoured to the bone and the fracture pattern for a firm fixation. In comparison with the dynamic compression plate the reconstructive plate was lighter and thinner and it was durable in multi-directional mechanical stress that was imposed at the fracture site.

Ghanem *et al.* (2011) reported that 2.3 mm reconstruction bone plates provided excellent stability and healing of the unstable infected mandibular fractures, provided that the fracture site was fixed by at least 3 screws on each side of the fracture sites.

Woltz *et al.* (2016) opined that reconstructive plates had a lower profile than standard compression plates with a concentrated mass around the screw holes. These characteristics reduced the plate stiffness and facilitated easy contouring in all planes to fit the anatomic shape of the long bones.

Primeau *et al.* (2018) reported that locking plates provided better stability and resistance to higher load bearing, resulted in an earlier return to complete weight bearing and allowed patients to return to work. Locking plates might also decreased the number of post-operative complications related to bone healing (*e.g.,* non-union). However, non-locking plates were cheaper than locking plates. Due to their bulkiness and material properties, they could cause irritation, which might require surgical removal of the plate.

Hosmani (2019) used stainless steel locking and non-locking reconstruction plates for tibiotarsus fracture repair in backyard poultry and observed that locking reconstruction plates provided more stability than non-locking plates.

Pallavi (2021) used stainless steel and titanium locking reconstruction plates for tibiotarsus fracture repair in backyard poultry and observed that stainless steel locking reconstruction plate provided more stability than titanium plate.

2.11.2 Veterinary cuttable plate

Brüse *et al.* (1989) reported that veterinary cuttable plates were commonly used to stabilize small animal long bone fractures. They also reported that veterinary cuttable plates allowed for placement of multiple screws in relatively short bone fragments on account of the large number of screws per unit length as compared with dynamic compression plates, least contact dynamic compression plates or locking compression plates. They also reported that sandwiching of veterinary cuttable plates was a method of placing one plate on top of another in order to increase the degree of stiffness. This might be done with two plates of the same or different lengths and thickness. When sandwiching plates of different thicknesses, the screw diameter was decided by the thinner plate's holes. When sandwiched plates were simultaneously contoured, the largest possible screw placed in the end holes of the plates would minimize slippage. Options when sandwiching plates were: 1. Full - the two plates are of the same length, 2. Three quarters - the upper plate has approximately $3/4^{th}$ the length of the lower plate and 3. Half - the upper plate has approximately half the length of the lower plate. Sandwiching allowed the surgeon to vary the plate rigidity according to the fracture situation. Partial sandwiching (three-quarters or one half)

decreased the plate stiffness at the plate ends. Large number of plate holes per unit of length which allowed not only fixation of very short main fragments in comminuted fractures that otherwise would be impossible to include beneath the plate.

Howard (1990) reported that the association for the study of internal fixation 30 cm 50-hole veterinary cuttable plate was ideal for the treatment of avian fractures.

McLaughlin *et al.* (1992) reported that stacked veterinary cuttable plates were used with excellent results for bridging osteosynthesis in comminuted diaphyseal fractures of the femur in cats.

Cabassu (2001) reported that elasticity at the fracture site was achieved by using veterinary cuttable plates. Twenty-four dogs, with unilateral fractures of the femur which were repaired using veterinary cuttable plates and accommodating 2.0 or 2.7 screws employed in 23 out of 24 cases. All the screws selected were 2.7 mm in size. The small veterinary cuttable plate with 2.0 mm screws was used once. The plates were applied according to the principles of bridge plating.

Dowling *et al.* (2001) reported that use of cuttable bone plates should be considered as a reasonable alternative to interfragmentary wiring for unstable, comminuted fractures of the facial bones, even where fractures were open.

Gemmil *et al.* (2004) reported that carpal bone agenesis and bifurcation of the distal radial physis in cat were treated by ante-brachio metacarpal arthrodesis using dorsal stacked 1.5 mm veterinary cuttable plates and a supplementary cross pin. Following the operation, the cat gained good use of the affected limb.

Davidson *et al.* (2005) reported that a 6-hole, 1.5 mm or 2.0 mm veterinary cut-to-length plate successfully immobilised a coracoid fracture in a bald eagle.

Hammel *et al.* (2006) concluded that stacked veterinary cuttable plates constructs have greater fatigue lives than comparably sized least contact dynamic compression plates or single constructs. Plates with 2.4 mm screws were not significantly different from the comparable construct with 2.0 mm screws.

Théoret and Moens (2007) reported the use of veterinary cuttable plates in 9 animals and got some complications like pressure sores in 2 cases, 5 and 6 weeks after surgery. These received local treatment and bandage changes. One screw loosening was noted in another case, 4 weeks post-operatively and was treated with screw removal and antibiotics.

Sarrau *et al.* (2007) opined that due to the elasticity obtained using a long veterinary cuttable plate alone, it could also be used as a bridging construct for young dogs and reduced the stress applied to the points of the fixation (the screws and bone). It provided greater interfragmentary micromovements to stimulate a more voluminous callus.

Hamilton *et al.* (2009) reported that 21 cats were treated for ileal fracture with veterinary cuttable plate of size 2.0 mm or 2.7 mm. Screw loosening was observed in 13 cases.

Rose *et al.* (2009) concluded that a four-hole partially stacked veterinary cuttable plate (either 1.5/2.0 or 2.0/2.7 mm) had comparable mechanical properties to fully stacked veterinary cuttable plate.

Ramesh *et al.* (2018) reported that six immature young dogs having femoral diaphyseal fractures were stabilized with indigenously designed 2.0 mm and 2.7 mm veterinary cuttable plates. Veterinary cuttable plates with cortical screws maintained good implant stability in four dogs. Plate bending at the fracture site was encountered by the 15th post-operative day in one dog and distal screw loosening was observed by the 30th day in another dog. However, post-operatively, all six cases showed complete weight bearing in an average of 30 to 45 days.

Zellner *et al.* (2018) reported that the use of a veterinary cuttable plate was successful for tendon repair in dogs.

Doijode (2018) concluded that the veterinary cuttable plate provided sufficient stability at the fracture site and was affordable and economic to use for internal fixation in goats. He got complications like slight bending of plates which might have been due faulty management or due to slightly heavy weight of the animal.

Macedo and Moens (2018) reported that veterinary cuttable plate were available in 2 sizes: 1.5/2.0 veterinary cuttable plate accepted 1.5 mm and 2.0 mm screws whereas 2.0/2.7 veterinary cuttable plate accepted 2.0 mm, 2.4 mm and 2.7 mm screws. These veterinary cuttable plate were available in 50-hole lengths and might be cut to the desired length before sterilization or just before application. They also reported that surgical repair of the right zygomatic arch fracture was performed with open reduction and stabilization with an 11-hole, 2.7 mm veterinary cuttable plate and fracture healing occurred without complication.

Vedrine and Gérard (2018) reported that the high amount of screw holes per unit length of a veterinary cuttable plate allowed bi-cortical screw placement without interfering with the intramedullary rod in a plate rod construct.

2.12 POST- OPERATIVE CARE

2.12.1 Post-operative medication

Bush (1977) recommended gentamicin sulphate at 8 mg/kg twice a day in a red-tailed hawk with tibiotarsus fracture treated by external skeletal fixation.

Harcourt-Brown (2002) reported that carprofen could be used to control pain by subcutaneous administration for 4 to 5 days. Meloxicam was also useful and can be given daily for long periods with apparent beneficial effects.

Hollamby *et al.* (2004) recommended that 250 mg of calcium and 125 IU of vitamin D (as cholecalciferol) orally once a day for 20 days and vitamin B supplementation orally once a day for 3 days were recommended for post-operative management of tibiotarsus fracture repair in a bald eagle using an interlocking nailing.

Davidson *et al.* (2005) suggested that after the plate fixation of a coracoid fracture in a bald eagle, enrofloxacin given at 15 mg/kg once a day orally before the surgery and 8 days post surgically. Butorphanol tartrate (2 mg/kg orally twice a day) was continued for 15 days after surgery as an analgesic.

Guzman *et al.* (2007) opined that enrofloxacin at 15 mg/kg and meloxicam at 0.2 mg/kg orally once a day were given for 12 days for tibiotarsus fracture repair of bald eagle using plate rod technique.

Hoybergs *et al.* (2008) reported that the post-operative analgesia used was meloxicam at 0.5 mg/kg body weight after surgical correction of tarsometatarsal fracture in a Harri's hawk. They also advised that it was less toxic for scavenging birds compared to flunixin, carprofen and diclofenac.

Johnston *et al.* (2008) suggested oral meloxicam at 0.3 mg/ kg and enrofloxacin 10 mg/kg orally twice a day was used for post-operative management of bone transport osteogenesis for reconstruction of a bone defect in the tibiotarsus of a yellow-naped amazon parrot.

Gull *et al.* (2012) reported that post-operative analgesia was provided with carprofen at 4 mg/kg intramuscularly for 3 days. Chlortetracycline at 1 g/L in drinking water was administered for 7–10 days as an antibiotic treatment in post-operative care of fracture stabilization with plating in pigeons.

Nanjappa *et al.* (2013) opined that post-operatively meloxicam was given at 0.5 mg/kg intramuscularly once daily for 5 days and enrofloxacin at of 20 mg/kg intramuscularly once daily for 7 days was used in unilateral wing amputation for the management of humerus fracture in a black kite.

Gayathri and Sunil (2018) suggested that ceftiofur sodium at 0.91mg/kg subcutaneously was given for 7 days as the antibiotic of choice in post-operative medication of humeral fracture treated with intramedullary pinning.

Dias *et al.* (2018) reported that meloxicam at 0.1mg/kg was given every 24 hours for four days after intramedullary pinning in white Plymouth rock birds.

Ozsemir and Altunatmaz (2021) reported that extremity fractures in 20 wild birds with a modified Meynard external fixator received ceftriaxone at 100 mg/kg intravenously as an antibiotic. As a pre-emptive analgesia, meloxicam was given at 0.5 mg/kg subcutaneously following induction. Post-operatively ceftriaxone was given at 100 mg/kg intramuscularly twice daily for 7 days and meloxicam at 0.5 mg/kg orally once a day as an analgesic for 3 to 5 days was given.

2.12.2 Post-operative immobilization

Bush (1977) reported that exposed sharp metal edges and fixation clamps must be padded, especially on the medial aspect to prevent self-inflicted trauma in fracture management of birds with external skeletal fixation.

Harcourt-Brown (2002) opined that the healing limb must be allowed to move as soon as possible in order to prevent adhesions and scarring. The fracture must be supported rigidly, however the joints might be allowed to move freely.

Davidson *et al*. (2005) suggested that the figure-of-eight bandage and body wrap were used for 4 weeks after surgery. They immobilized the pectoral girdle and minimized the likelihood of injury. Every 3 days, the bandages were changed.

Javdani and Nikousefat (2012) suggested that external coaptation using splint and bandage was used and the bird was compelled to cage rest with access to food and water for 7 weeks for repair of radial and ulnar fracture in a sparrowhawk using external coaptation.

2.12.3 Physical therapy

Ferraz *et al.* (2010) suggested that post-operatively, physical therapy was recommended for birds after the treatment of tarsal joint deformities with hinged trans articular external fixators in three young birds, which involved the owner performing passive range-of-motion exercises on the pelvic limb joints at least three times a day. After seven days of physical therapy, increased range-of-motion, which was subjectively evaluated, was appreciated in all of the joints. However, slight swelling in the joints was noted. At two weeks, the range–of-motion continued to increase and there was some weight-bearing noted. At three weeks, both birds were able to take a few steps without any assistance.

Bueno *et al.* (2015) suggested that physical therapy consisted of gentle manipulation of the affected leg and foot, alternately extending and flexing the stifle and intertarsal (hock) joints as well as the foot and toes for a few minutes in tie-in fixation for the repair of tibiotarsus fractures in raptors.

2.13 POST-OPERATIVE COMPLICATIONS

Bennett and Kuzma (1992) opined that osteomyelitis, bone sequestration and joint ankylosis continued to be major factors inhibiting healing and functional outcome in birds.

Kavanagh (1997) reported complications like secondary fracture disease such as mal-union which was prevented with prolonged disuse of the fractured leg. The limb musculature would become atrophic and joint capsules would fibrose causing reduced range of movement.

Harcourt-Brown (2002) opined that mal-union, non-union, osteomyelitis, osteoarthritis, septic arthritis, amputation of the digit after surgery and extensive bruising were common complications in avian orthopaedics. The skin around the injured site occasionally lost its blood supply and died. This condition might be caused by trauma, but it also could be iatrogenic. This blood loss happened suddenly and produces an area of dry gangrene, which also might include deeper structures.

Holz (2003) opined that healing without internal fixation often led to malunion and a shortened bone in treatment of coracoid fractures of bald eagle. Coracoid fractures might be stabilized with intramedullary pins or cortical plates.

Durrani *et al.* (2009) reported that pigeons anaesthetised by ketamine alone had a very rough induction due to lack of skeletal muscle relaxation, thus causing excitement. Xylazine-ketamine cocktail combination resulted in respiratory depression, bradycardia and hypothermia.

Hoybergs *et al.* (2008) reported that medium graded osteolysis around the distal pin and low graded osteolysis around the proximal pin were noticed in external skeletal fixation of a tarsometatarsal fracture in a Harris's Hawk.

Gull *et al.* (2012) reported that a high percentage of the screws had loosened, leading to failure where a limited contact system was created with washers that were placed between a 1.3 mm adaption plate and bone. The maxillofacial miniplates of birds were too weak and were bent.

Materials and Methods

III. MATERIALS AND METHODS

The experimental research on comparative evaluation of veterinary cuttable plate and locking reconstruction plate for tibiotarsus fracture repair in Aseel bird was carried out at Department of Veterinary Surgery and Radiology, Veterinary College, Bidar. The permission for conducting the experimental research was obtained by institutional animal ethical committee vide reference no. IAEC (No.17/2021/VCB/VSR).

3.1 SOURCE OF ASEEL BIRDS

The Aseel birds were recieved from ICAR-Directorate of Poultry Research, Rajendra Nagar, Hyderabad. A total of twenty birds of either sex, aged 9 weeks with body weight ranged from 1.0 - 1.5 kg were received for experimental research purpose.

3.2 HOUSE KEEPING OF ASEEL BIRDS

The birds were housed in the poultry shed on deep litter sytem of 4-5 cm layer thickness of paddy husk (Plate 1). The poultry shed was prepared one day advance before arrival of the birds with fumigation by mixing of 2 parts of formalin and 1 part potassium permanganate (40 mL + 20 g) for complete expulsion of gas. The proper lighting and ventilation was maintained inside the poultry shed with 200 W bulbs. The feeding and watering was carried out with commercially available poultry grower feed as per the BIS 2007 specification. On the day of arrival each aseel bird received oral two drops of multivitamin supplement[1] to compensate travel stress. Initially birds were given 15 days rest to get acclamatize the housed environment. As per the technical programme, 1 bird at

[1] Vimeral® - Anti-stress feed supplement – 500 mL - Virbac Animal Health India Pvt. Ltd., Mumbai.

each time was taken for surgical operation and housed individuly in a single cage. The operated birds were kept in the individual cages inside the poultry shed till recovery to avoid infighting injury and post operative complications (Plate 2).

3.3 DETAILED TECHNICAL PROGRAMME OF THE STUDY

The experimental research was conducted on 12 Aseel birds of either sex were randomly divided into 2 groups *viz.*, group I and II. In each group 6 birds were included for experimental study. In group I veterinary cuttable plate and in group II locking reconstruction plate were evaluated for repair of tibiotarsus fracture in Aseel birds. The details of technical programme for study was shown in Table 1.

3.4 PREPARATION OF ASEEL BIRD FOR ANAESTHESIA

On the day of surgery bird was fasted, for 3 hours and water withheld for 1 hour. Pre-operative enrofloxacin[2] antibiotic at the rate of 10 mg/kg body weight (Waxman *et al.*, 2021 and Verma *et al*., 2018) and meloxicam[3] as pre-emptive analgesia at the rate of 0.2 mg/kg body weight intramuscular (Pallavi, 2021) were given in the pectoral muscle of bird.

3.5 ANAESTHESIA

The repair of tibiotarsus fracture was performed under general anaesthesia using xylazine[4] at the rate of 5 mg/kg and after 5 minutes interval ketamine[5] at the rate of 70 mg/kg were given intramuscular in the pectoral muscle as suggested by (Pallavi, 2021).

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[2] Enrox® - Enrofloxacin injection IP – 100 mg/mL – 100 mL vial – Alembic Pharmaceuticals Ltd., Gujarat.
[3] Melonex® - Meloxicam injection IP – 5 mg/mL – 30 mL vial – Intas Pharmaceuticals Ltd., Ahmedabad.
[4] Xylaxin®- Xylazine Injection USP–30mL– vial-Indian Immunologicals Ltd., Telangana.
[5] Aneket®- Ketamine hydrochloride Injection IP – 5 mL vial–Neon Labarotaries Ltd., Mumbai.

3.6 INDUCTION OF TIBIOTARSUS BONE FRACTURE

Tibiotarasus fracture in each bird was induced in a humane manner after administration of general anesthesia. The bird was placed on the table in left lateral recumbency. The right leg was held by the both hands at stifle and hock joints and strong force was applied by thumb at mid-diaphyseal region of tibiotarsus for induction of fracture (Plate 3). Induction of fracture was confirmed by mal-alignment of fractured fragments and radiographic imaging.

3.7 PRE-OPERATIVE EVALUATION OF FRACTURE BY RADIOGRAPHY

Radiographs were taken before induction of fracture and after induction of fracture. Medio-lateral and cranio-caudal views of the fracture induced leg was taken for survey radiograph. The exposure factors were 43 kVp and 3 mAs for radiograph examination. The bird was positioned in right lateral recumbency for medio-lateral view of right leg and in sitting position for cranio-caudal view (Plate 4). The radiographs were processed using computerised radiographic processor[6]

3.8 INSTRUMENTATION AND IMPLANTS

3.8.1 General surgical instruments

General surgical instruments needed for skin dissection, blunt dissection, haemostasis and wound closure were included for tibiotarsus fracture repair with bone plating in Aseel birds.

[6] Computerised Radiography, Allergens, Medical System Ltd., Chandigarh.

3.8.2 Orthopaedic instruments used for bone plating of both the groups

Orthopaedic instruments used for bone plating of both the groups were bone cutter, bone ronger, drill sleeve for veterinary cuttable plate fixation, drill sleeve for reconstruction plate fixation, drill bit (2.0 mm), depth gauge, hexagonal screw driver and battery operated power driller (Plate 5).

3.8.3 Fixation implants used for stabilization of tibiotarsus fracture

Veterinary cuttable plate of 2.7 mm with non-locking self-tapping screws was used for fracture repair of tibiotarsus bone in group I Aseel birds (Plate 6). Locking reconstruction plate of 2.7 mm with self-tapping screws was used for fracture repair of tibiotarsus bone in group II Aseel birds (Plate 7). All the general surgical instruments, orthopaedic insturments and implants required for bone plating were sterilized by autoclave at 121°C for 15 minutes at 15lbs pressure while the battery operated power driller was sterilized using formaldehyde.

3.9 PREPARATION OF SURGICAL SITE

The surgical site was prepared by plucking of feathers around fracture site on medial aspect of tibiotarsus extending from stifle to hock joint. Sterile gauze bandage was wrapped from toes to hock joint to maintain asepsis and to prevent contamination of surgical site. To maintain normothermia the bird was placed on hot water bag in lateral recumbency (Plate 8). The surgical site was scrubbed with 1% chlorhexidine[7] solution in centrifugal direction and followed by 70% ethyl alcohol. The incision site was smeared

[7] Savlon – Chlorhexidine Gluconate and Cetrimide Solution – 100mL – ITC Ltd., New Delhi.

with 5% povidone iodine solution for production of asepsis at surgical site and draped as suggested by (Nanjappa *et al.*, 2013).

3.10 SURGICAL PROCEDURE

Cranio-medial approach was selected for repair of tibiotarsus fracture as suggested by Slunsky *et al*. (2018). An incision was made on skin extending from the stifle joint proximally to hock joint distally. After incision, the skin and fascia were separated with precaution not to damage subcutaneous artery present at proximal third part of tibiotarsus bone (Plate 9). The muscle bellies of fibularis longus and gastrocnemius were dissected by cutting fascia. Cranially fibularis longus, caudally gastrocnemius muscles were retracted to expose both proximal and distal fragments of tibiotarsus (Plate 10). The haematoma present at the fractured site was cleared by washing with normal saline. In both the groups open reduction was done and fractured fragments were manually reduced by applying traction and counter traction. After the anatomical reduction of fractured fragment, the desired length of veterinary cuttable plate/locking reconstruction plate was placed on medial aspect of tibiotarsus bone.

In group I, veterinary cuttable plate of 10 holes with 2.7 mm thickness was applied on medial aspect of aligned fractured fragments of tibiotarsus. The drill sleeve placed over the plate hole firstly near to the fracture site either proximal or distal segment. Hole was drilled through the drill sleeve with battery operated low speed power driller using 2 mm drill bit. To avoid thermal necrosis at the time of drilling normal saline was poured into the drill sleeve (Plate 11). The drilled hole was purchased both cis and trans cortex by self-tapping non-locking screw of desired length using hexagonal screw driver (Plate 12). In

similar fashion all the remaining holes were drilled and purchased by self-tapping non-locking screws. It was ensured that all screws were properly tightened and holding the plate in situ for stabilization of fractured fragments (Plate 13). The repaired site was thoroughly washed with normal saline diluted with povidone iodine to remove all the tissue debris and blood clots. Muscular fascia of respective muscle bundles was sutured by using 2-0 monofilament poliglecaprone 25[8] with lock stitch suture pattern (Plate 14). The skin was sutured with 2-0 monofilament polypropylene[9] with simple interrupted suture pattern (Plate 15). The sutured site was cleaned with povidone iodine and dressed with sterile gauze (Plate 16). The bird was monitored and kept under observation till complete recovery from the anaesthesia. The operated bird was shifted to individual cage in the poultry shed.

In group II locking reconstruction plate of 10 holes with 2.7mm thickness was applied on medial aspect of aligned fractured fragments of tibiotarsus bone. The similar procedure was followed as explained in group I birds for tibiotarsus fracture repair (Plate 17 to 22).

3.11 POST-OPERATIVE CARE AND MANAGEMENT

The post-operative dressing of surgical site was done by light weight sterile bandages. Bandage was changed alternative days up to suture removal. Skin sutures were removed on 7^{th} to 14^{th} post-operative day after ensuring the healed skin.

Enrofloxacin drop at the dose rate of 10 mg/kg once daily for five days and meloxicam at the dose rate of 0.2 mg/kg intramuscular for three days were given to control

[8] Monoglyde – Monofilament poliglecaprone 25 – Healthium Medtech Pvt Ltd., Bengaluru.
[9] Trulene – Monofilament polypropylene - Healthium Medtech Pvt Ltd., Bengaluru.

post-operative infection and inflammation at the fractured site. Oral calcium[10] of 0.2 mL and oral multivitamin supplement of 0.2 mL were administered with the help of tuberculin syringe daily once for 14 days and for 7 days respectively. Physiotherapy of operated leg was done on alternative days for 14 days.

3.12 EVALUATION OF STUDY

3.12.1 Clinical evaluation

Clinical evaluation of operated birds were observed till healing of fracture. The observations recorded were limping, swelling, weight bearing, gait and wound healing at different intervals on pre-operatively, immediately after surgery on day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups.

3.12.1.1 Weight bearing

The weight bearing of the operated leg was evaluated by the weight bearing score chart given by Fox *et al.* (1995) as showed in Table 2.

Evaluation of weight bearing of affected leg was done pre-operatively immediately after surgery on day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups.

3.12.1.2 Lameness score

The lameness grading of the operated leg in birds was evaluated for lameness score as mentioned by Kestin *et al.* (1992) as showed in Table 3.

[10] Calshakti – Liquid animal feed supplement – 500mL – Intas Pharmaceuticals Ltd., Ahmedabad

Evaluation of operated leg in birds for lameness score was done pre-operatively, immediately after surgery on day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups

3.12.2 Radiological evaluation of fracture healing

The radiological scoring of the operated leg was evaluated for fracture healing with radiological scoring system suggested by Tunio *et al*. (2014) as showed in Table 4.

Radiological evaluation of operated leg in birds for fracture healing with radiological scoring was done pre-operatively, immediately after surgery on day 0 , 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups.

3.12.3 Computed Tomographic Evaluation of fracture healing

Computed tomographic evaluation of fracture healing of operated leg in birds was done with computed tomographic image done immediately after surgery on 7^{th} , 14^{th} and 30^{th} post-operative days in both groups.

3.13 STATISTICAL ANALYSIS

After obtaining the relevant information regarding the variations in the linical and radiological parameters and they will be compared at different intervals within the groups andwill be analyzed using the student “t” test and between the groups comparison will be analyzed by using the analysis of variance technique (Snedecor and Cochran, 1994).

Table 1. Design of research programme

Group	Number of Aseel birds	Anaesthetic protocol	Surgical condition	Type of plate used in fracture repair
I	**6**	Xylazine at the rate of 5 mg/kg intramuscular, after a gap of 5 minutes Ketamine at the rate of 70 mg/kg intramuscular	Tibiotarsus fracture	2.7 mm Veterinary cuttable plate
II	**6**	Xylazine at the rate of 5 mg/kg intramuscular after a gap of 5 minutes Ketamine at the rate of 70 mg/kg intramuscular	Tibiotarsus fracture	2.7 mm Locking reconstruction plate

Table 2: Weight bearing score chart as per Fox *et al*. (1995)

Description	Category
Full weight bearing	Excellent
Slight lameness after exercise	Good
Slight to moderate lameness however consistent weight bearing	Fair
Non-weight bearing lameness	Poor

Table 3: Lameness score based on Kestin gait-scoring system

Gait score	Degree of Impairment	Criterion
0	None	No detectable abnormality
1	Detectable and unidentifiable abnormality	Slight defect in walking ability that is difficult to define precisely. An uneven gait
2	Identifiable abnormality that has little effect on overall function	Definite and identifiable defect in gait with little hindrance of movement
3	Identifiable abnormality that impairs function	Obvious gait defect, which affects ability to move about
4	Severe impairment of function, still capable of walking	Severe gait defect. Capable of walking with difficulty when driven or strongly motivated. Squats at first opportunity
5	Complete lameness	Bird cannot walk. May shuffle on shanks or hocks with assistance of wings

Table 4: Radiological Scoring System based on Tunio *et al*. (2014)

Criteria	Observation	Score
Bone Union	Non union	0
	Secondary union	1
	Primary Union	2
Fracture Line	Visible	0
	Partial Visible	1
	Absent (Clinical Union)	2
Callus Formation	No Callus	0
	Minimal Callus	1
	Extensive Callus	2

Plate 1: Photograph showing Aseel birds were reared in the poultry shed in deep litter system at Veterinary College, Bidar

Plate 2: Post operative management of Aseel bird in a cage housed in poultry shed

Plate 3: Photograph showing manual induction of tibiotarsus fracture in an Aseel bird under general anesthesia

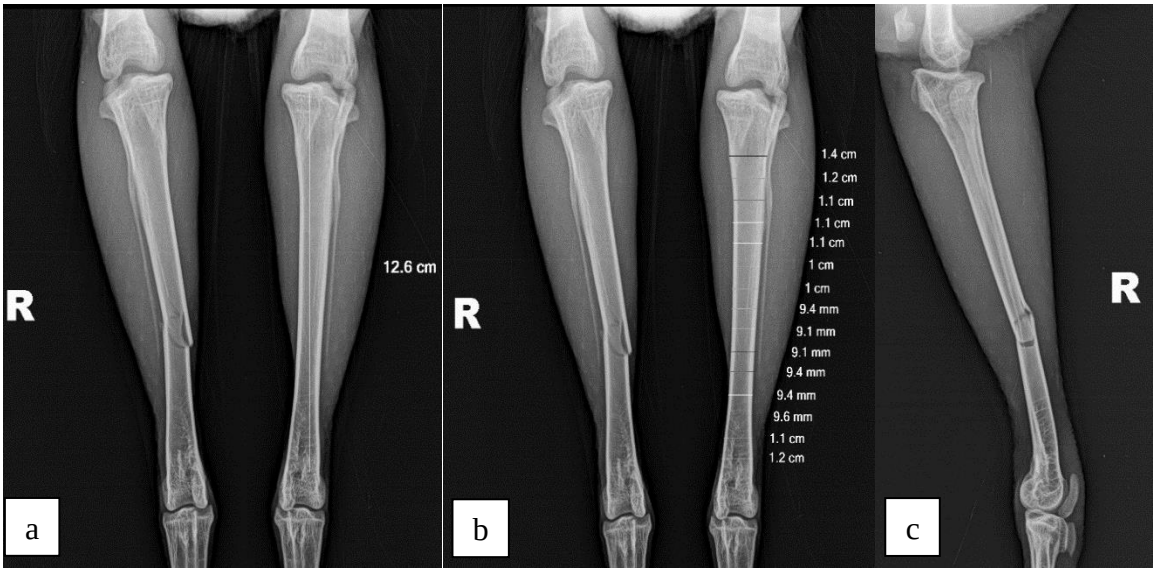


Plate 4: Pre-operative cranio-caudal (a,b) and medio-lateral (c) radiographic view for measurement of length and breadth at metaphyseal and diaphyseal region of tibiotarsus bone after induction of fracture in Aseel bird for both the groups

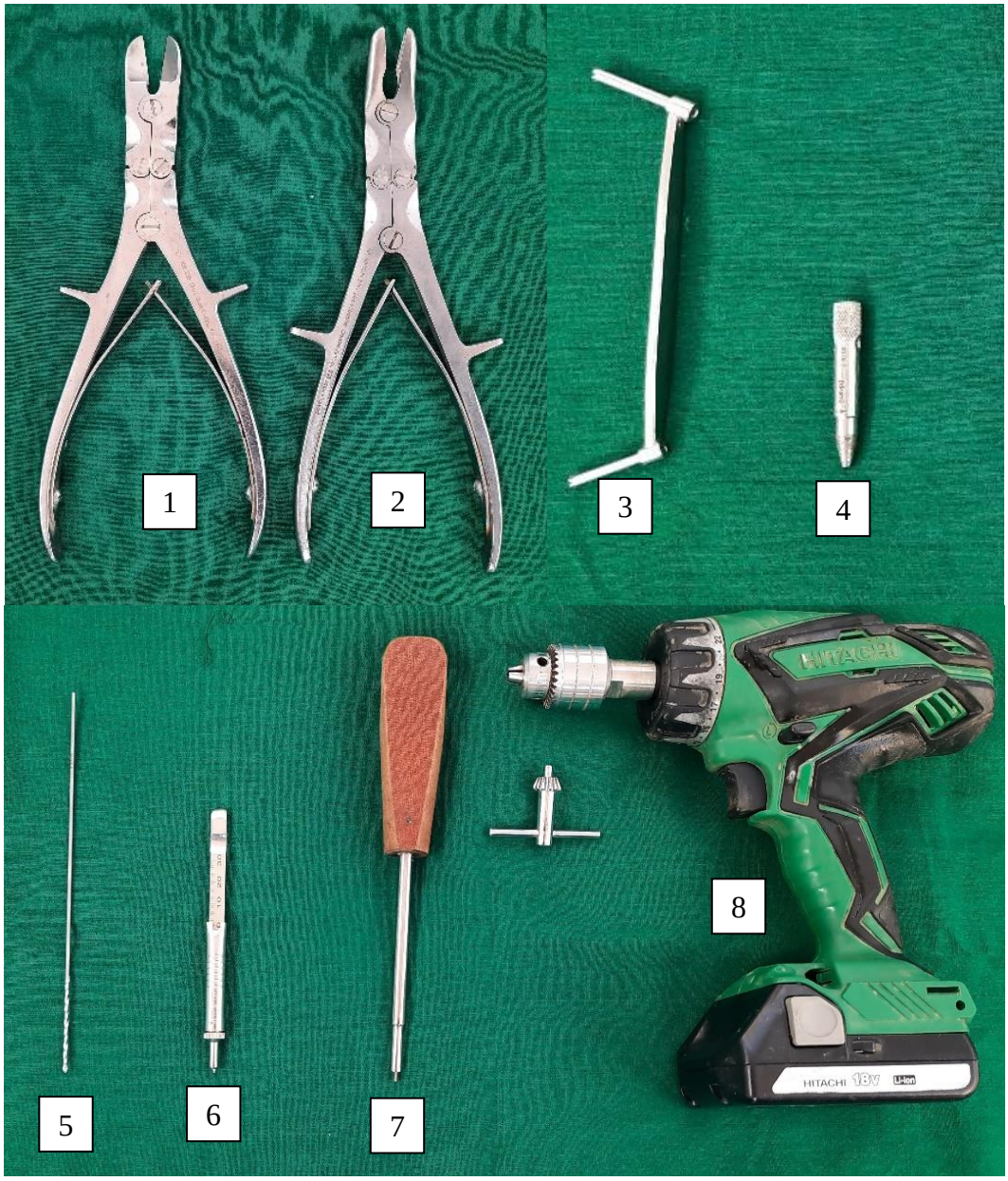


Plate 5: Orthopaedic instruments used for bone plating in Aseel birds

1. Bone cutter
2. Bone ronger
3. Drill sleeve for veterinary cuttable plate fixation
4. Drill sleeve for reconstruction plate fixation
5. Drill bit (2.0 mm)
6. Depth gauge
7. Hexagonal screw driver for 2.7 mm screws
8. Battery operated Power driller with key

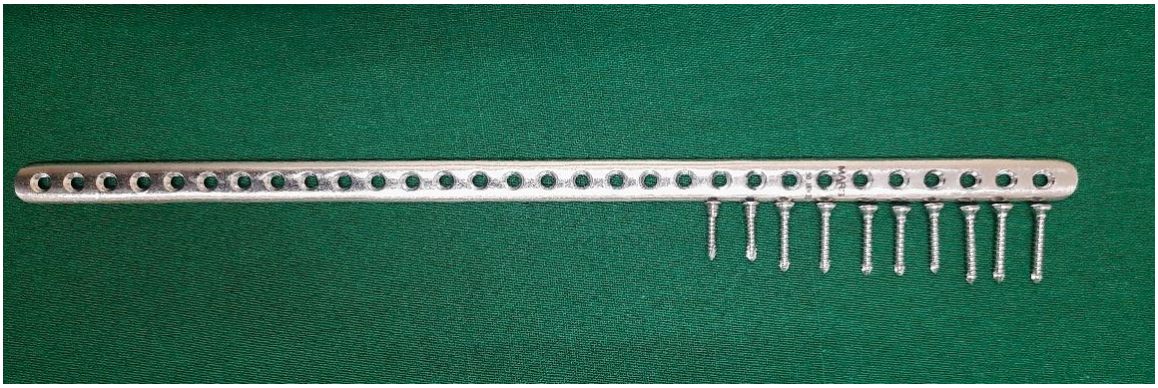


Plate 6: Veterinary cuttable plate of 2.7 mm and non-locking self-tapping screws of various size ranged from 12 mm-18mm were used in group I

Plate 7: Locking reconstruction plate of 2.7mm and self-tapping screws of various size ranged from 12 mm-18 mm were used in Group II

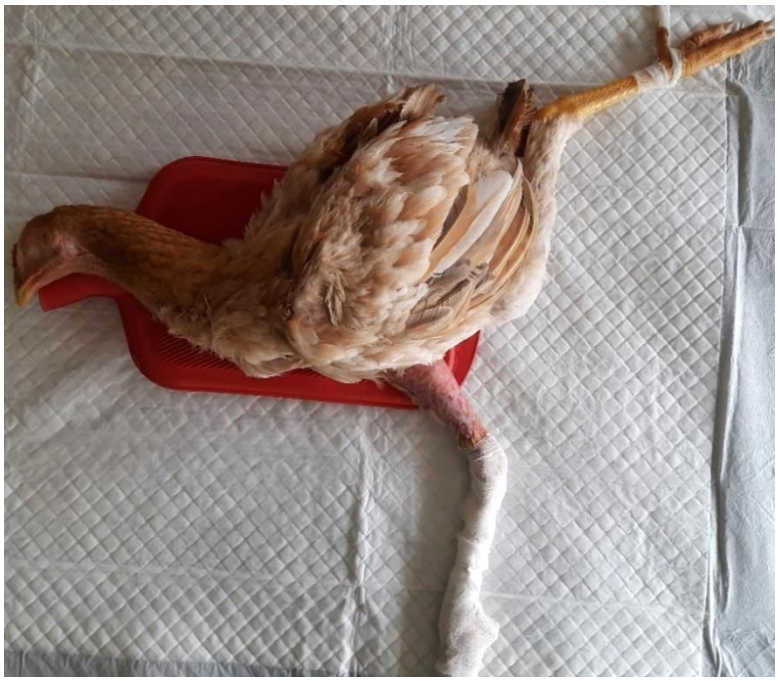


Plate 8: Photograph showing right lateral position of bird placed on hot water bag with the fractured right leg bandaged from hock to toes

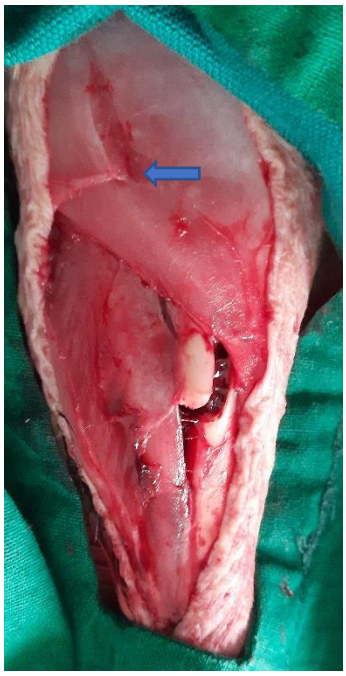


Plate 9: Photograph showing cutaneous artery (arrow marked) is a branch of tibialis anterior artery supplied through the gastrocnemius muscle in proximal third of the leg

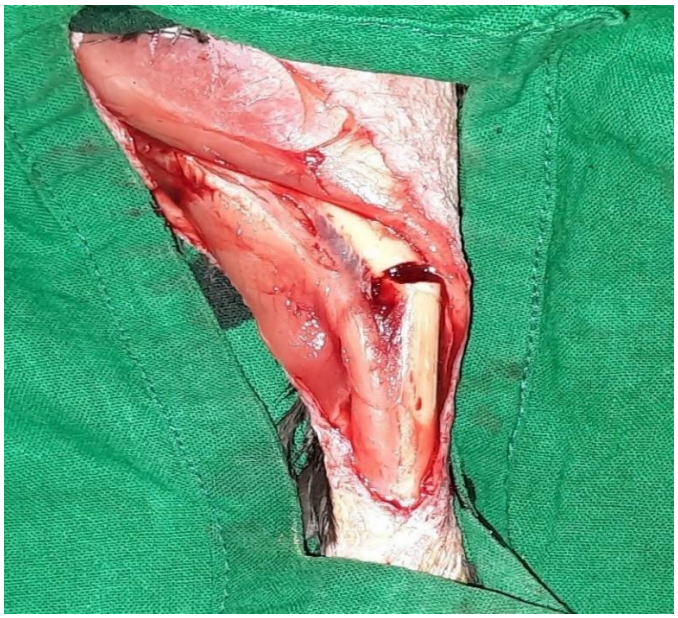


Plate 10: Photograph showing cranio-medial approach extended from stifle to hock joint for exposure of both proximal and distal fractured fragments at diaphyseal region of tibiotarsus bone in an Aseel bird the line of incision extended from stifle to hock joint

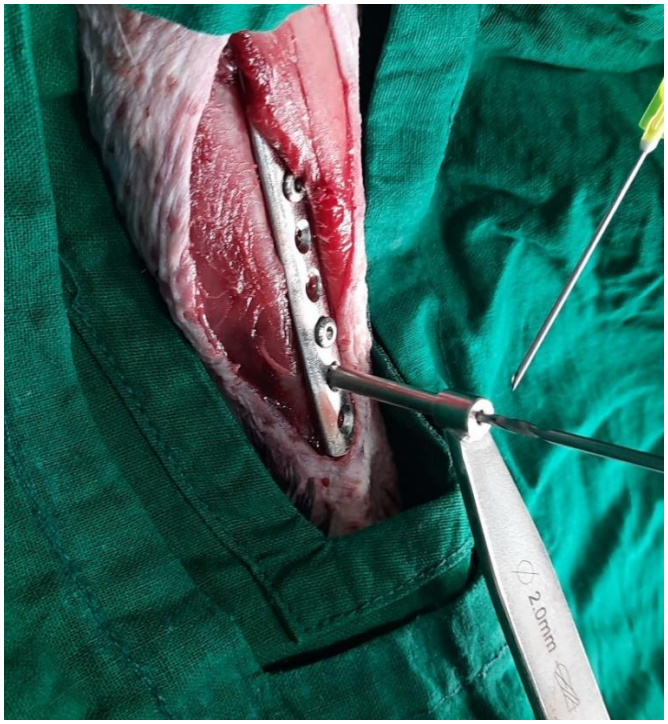


Plate 11: Photograph showing drilling of hole in the bone through drill sleeve using 2.0 mm drill bit for veterinary cuttable plate fixation in Aseel bird of group I

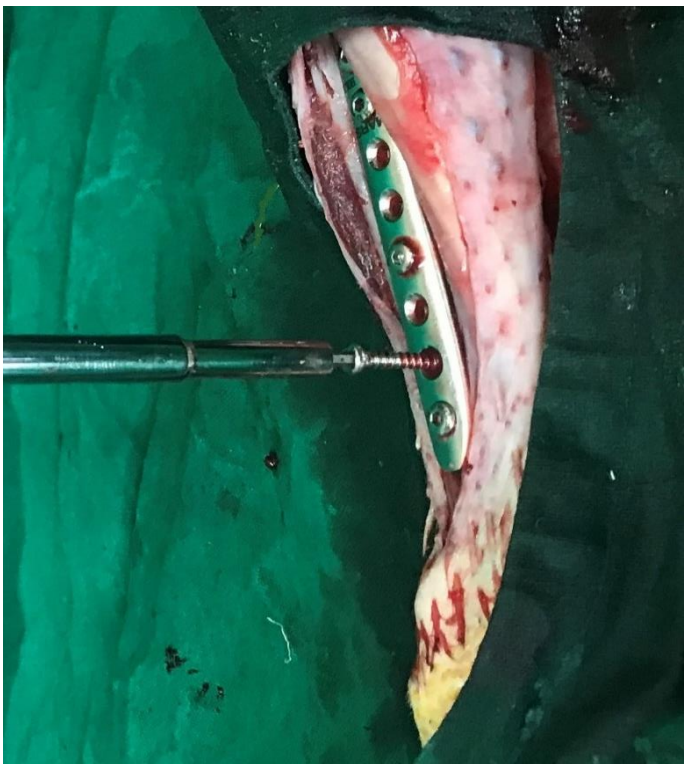


Plate 12: Photograph showing driving of non- locking self tapping screw with screw driver for veterinary cuttable plate fixation in group I

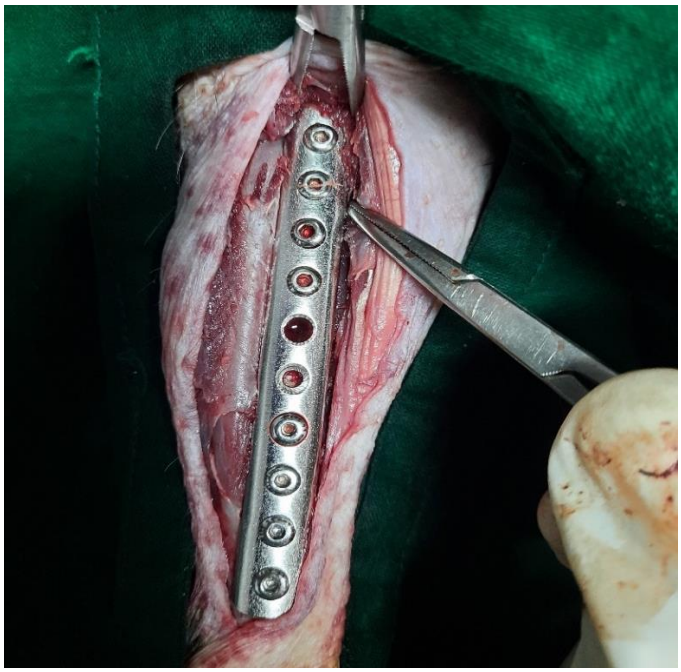


Plate 13: Photograph showing stabilization of tibiotarsus fractured fragments with 10 holes veterinary cuttable plate in an Aseel bird of group I

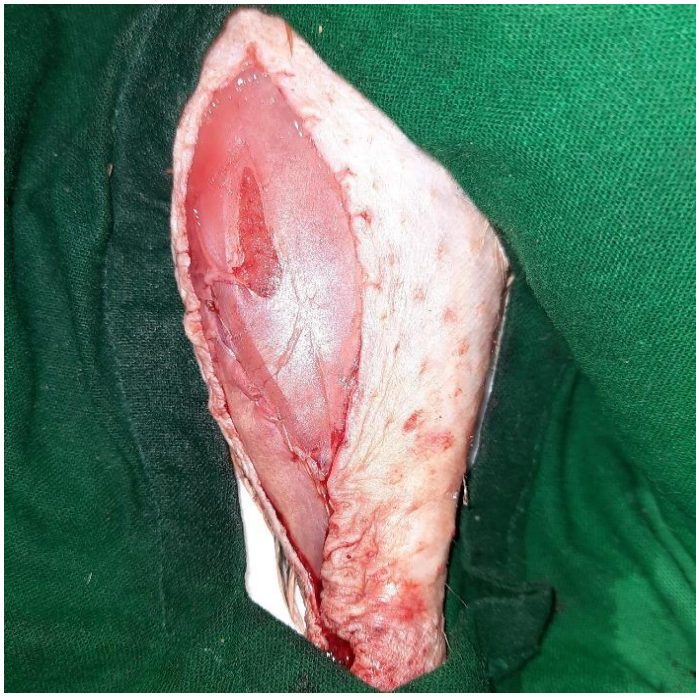


Plate 14: Photograph showing closed muscular fascia of gastrocnemius and fibularis longus with lockstich pattern using 2-0 poliglecaprone 25 after fracture repair in an Aseel bird of group I

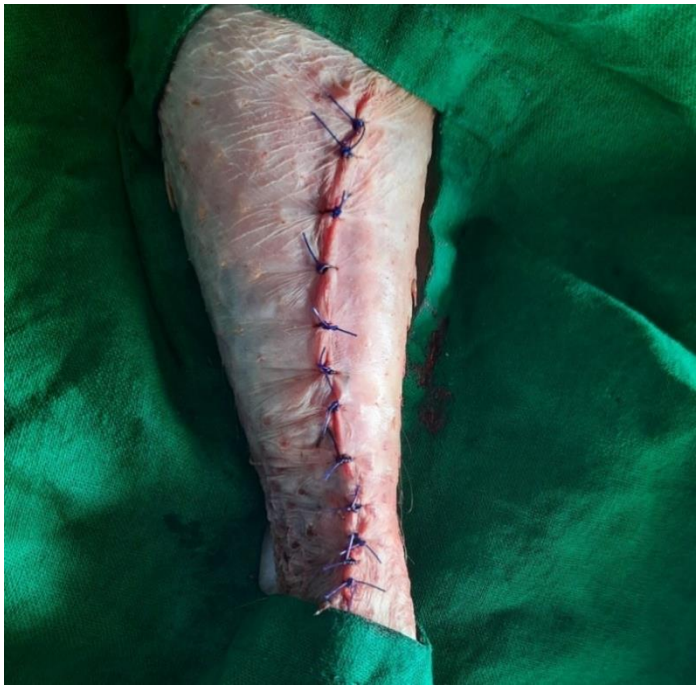


Plate 15: Skin sutured with interrupted pattern using 2-0 polypropylene in Aseel bird of group I

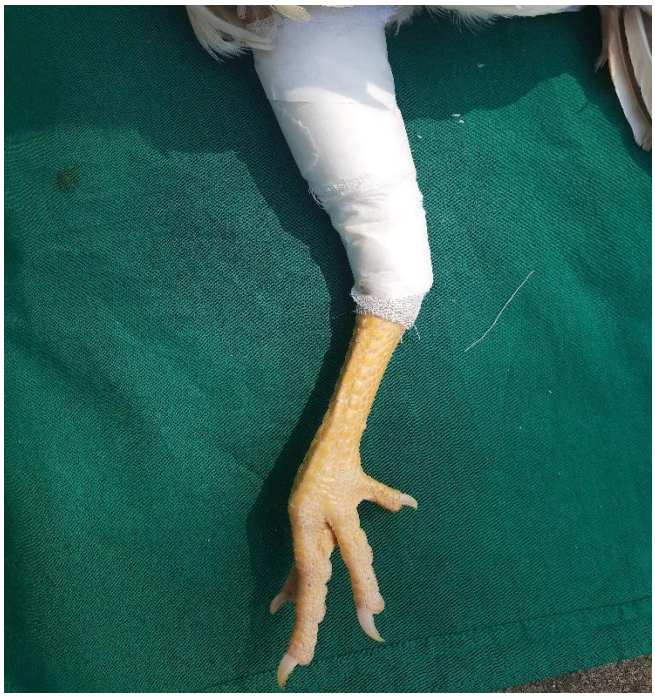


Plate 16: Photograph showing operated leg of group I Aseel bird dressed with sterile gauge bandage

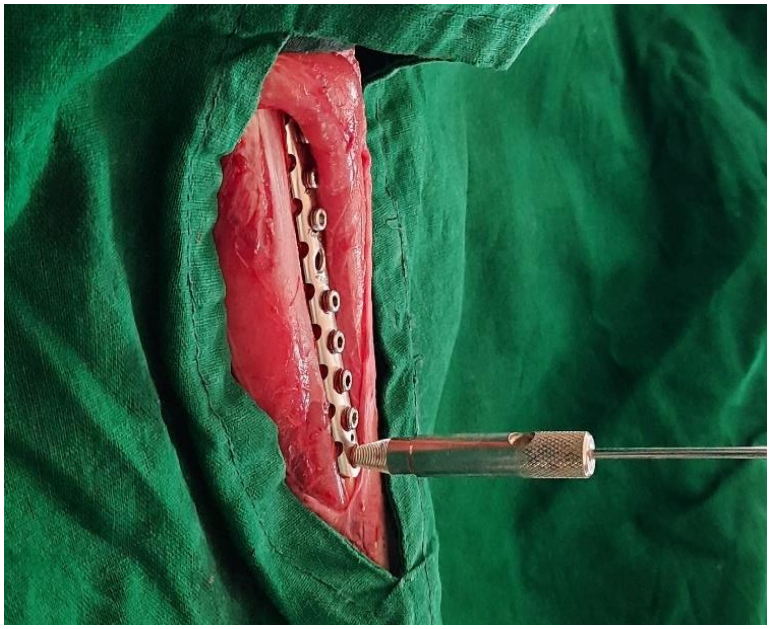


Plate 17: Photograph showing drilling of hole in the bone through drill sleeve using 2.0 mm drill bit for locking reconstruction plate fixation in Aseel bird of group II

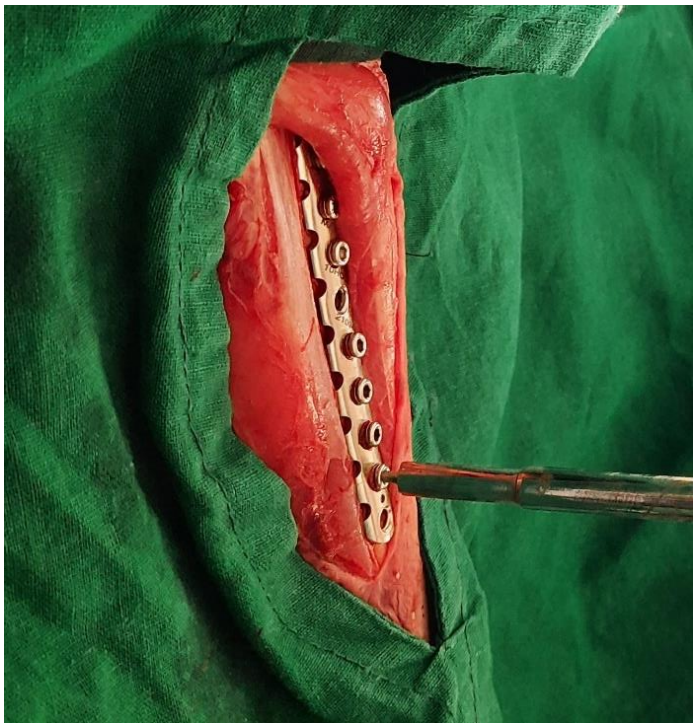


Plate 18: Photograph showing driving of self tapping screw with screw driver for locking reconstruction plate fixation in group II

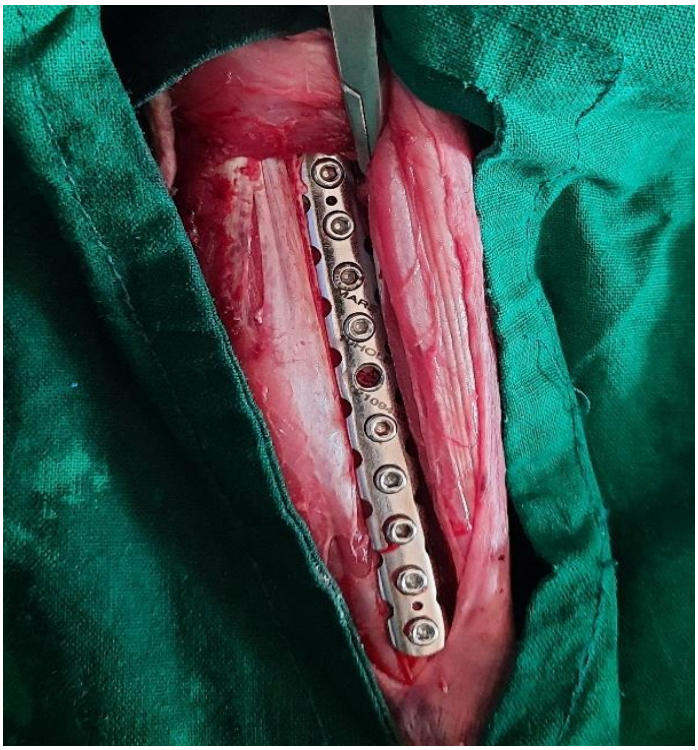


Plate 19: Photograph showing stabilization of tibiotarsus fractured fragments with 10 holes reconstruction plate in an Aseel bird of group II

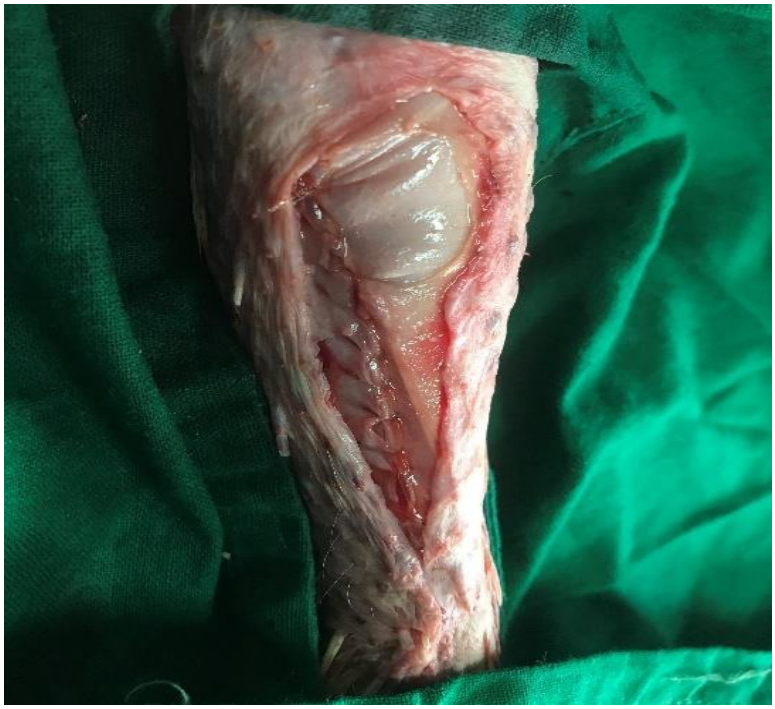


Plate 20: Photograph showing closed muscular fascia of gastrocnemius and fibularis longus with lockstich pattern using 2-0 poliglecaprone 25 after fracture repair in an Aseel bird of group II

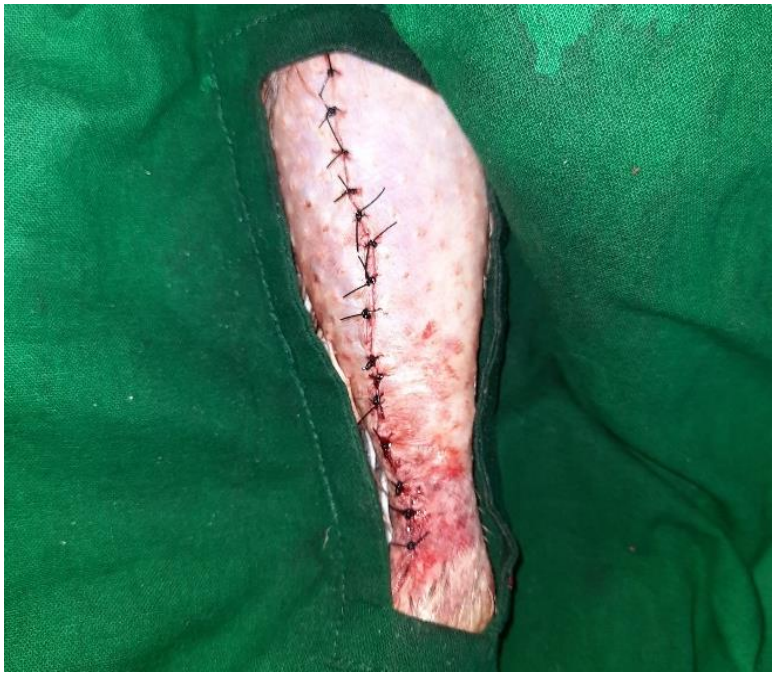


Plate 21: Skin sutured with interrupted pattern using 2-0 polyamide in an Aseel bird of group II

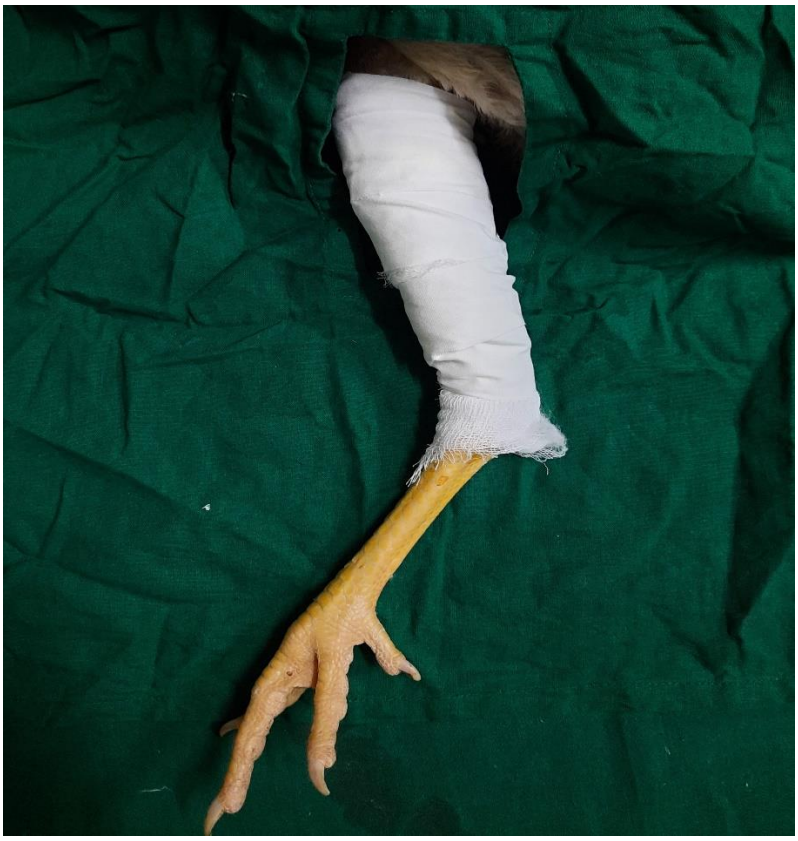


Plate 22: Photograph showing operated leg dressed with sterile gauge bandage in an Aseel bird of group II

Results

IV. RESULTS

The experimental research on comparative evaluation of veterinary cuttable plate and locking reconstruction plate for tibiotarsus fracture repair in Aseel bird was carried out at Department of Veterinary Surgery and Radiology, Veterinary College, Bidar. The experimental research results were discussed below.

4.1 HOUSE KEEPING OF ASEEL BIRDS

The birds were housed in the poultry shed on deep litter system of 4-5 cm layer thickness of paddy husk for a period of 6 months. All the 20 birds were healthy and attained adequate growth rate with in the study period. The poultry shed was spacious and well ventilated which prevented ammonia odour in the shed. The feeding and watering were carried out as per the standard of BIS 2007. Complications were not observed in the rearing of Aseel birds in this system. The operated birds were kept in the individual cage inside the poultry shed till recovery which avoided infighting injury and post operation complications. The cage management for operated birds helped in early recovery from fracture repair during the study period and avoided fracture complications and fracture disease.

4.2 PREPARATION OF ASEEL BIRD FOR ANAESTHESIA

On the day of surgery, each bird was fasted for 3 hours and water withheld for 1 hour. Pre-operative enrofloxacin antibiotic at the rate of 10 mg/kg body weight intramuscular prevented post-operative infection and meloxicam as pre-emptive analgesia at the rate of 0.2 mg/kg body weight intramuscular were given in the pectoral muscle of

bird. In both groups all the birds did not show any untoward incidences which makes them unfit for anaesthesia. The protocol followed was found satisfactory.

4.3 ANAESTHESIA

The tibiotarsus fracture repair was performed under general anaesthesia using xylazine at the rate of 5mg/kg and after 5 minutes interval ketamine at the rate of 70 mg/kg were given intramuscular in the pectoral muscle. All birds got anesthetised and attained surgical plane at average of 120 seconds. General anaesthesia was adequate enough to carry out tibiotarsus fracture repair with muscle relaxation, analgesia and unconsciousness and recovery from anaesthesia was also smooth and took average of 3 hours. In any bird of both the group incremental dose was not given and no anaesthetic complications were observed during the present study.

4.4 INDUCTION OF TIBIOTARSUS FRACTURE

Tibiotarsus fracture in each bird was induced manually. In all the birds simple oblique, transverse, communiated and oblique communiated fracture of tibiotarsus were observed. Induction of fracture was confirmed by mal-alignment of fractured fragments and radiographic imaging.

4.5 PRE-OPERATIVE RADIOGRAPHIC EVALUATION AND SIGNALMENT OF BIRDS FOR TIBIOTARSUS FRACTURE REPAIR WITH BONE PLATING

The average length of the tibiotarsus bone of contralateral leg in group I was 13.25±0.38 cm and in group II was 13.05±0.39 cm.

The average width of proximal fractured fragment at the first screw purchase site on tibiotarsus bone was 12.00±0.51 mm in group I and 11.60±0.21 mm in group II.

The average width of distal fractured fragment at the last screw purchase site on tibiotarsus bone was 10.77±0.54 mm in group I and 10.33±0.21 mm in group II. The values were mentioned in Table 6.

In group I, average body weight of bird was 1.39±0.02. All 6 birds had simple fractures and out of 6 birds, 4 had diaphyseal, 1 proximal-metaphyseal and 1 distal-metaphyseal fracture of tibiotarsus bone.

With respect to line of fracture among 6 birds, 4 had oblique, 1 transverse, 1 communiated fracture. The details were mentioned in Table 5.

In group II, average body weight of bird was 1.38±0.04. All 6 birds had simple fractures and out of 6 birds, 5 had diaphyseal and 1 metaphyseal fracture of tibiotarsus bone.

With respect to line of fracture among 6 birds, 3 birds had oblique, 2 transverse, 1 oblique-communiated fracture. The details were mentioned in Table 5.

4.6 FIXATION IMPLANTS FOR FRACTURE REPAIR OF TIBIOTARSUS BONE

In group I fracture of tibiotarsus was repaired with 10 holes veterinary cuttable plate. Among 6 birds the 4 birds were repaired by purchasing 8 holes, 1 bird with 9 hole and 1 bird with 7 holes in veterinary cuttable plate. The screw opted for fixation of

veterinary cuttable plate were non-locking, self-tapping with average length ranged from 16mm to 18mm. The details were given in Table 6.

In group II 5 fracture of tibiotarsus was repaired with 10 holes locking reconstruction plate and 1 with 12 holes locking reconstruction plate. Among 6 birds the 5 birds were repaired by purchasing 9 holes and 1 bird with 10 holes in locking reconstruction plate. The screw opted for fixation of plate were locking, self-tapping with average length ranged from 16mm to 18mm. The details were given in Table 6.

4.7 PREPARATION OF SURGICAL SITE

The surgical site was prepared by plucking of feathers around fracture site on medial aspect of tibiotarsus extending from stifle to hock joint. Sterile gauze bandage was wrapped from toes to hock joint which helped to prevent contamination of surgical site. Placement of bird on hot water bag in lateral recumbency prevented bird from hypothermia. Scrubbing of surgical site with 1% chlorhexidine solution, 70% ethyl alcohol and 5% povidone iodine solutions in centrifugal direction helped to maintain asepsis at operative site.

4.8 SURGICAL PROCEDURE

Cranio-medial approach was selected for repair of tibiotarsus fracture. An incision was made on skin extending from the stifle joint proximally to hock joint distally. At distal end of tibiotarsus bone slight modification was made in the line of incision, the incision was shifted from cranio-medial to cranial avoided the damage to the tibial vein and prevented the wound dehiscence after skin closure. The incision length was adequate

enough to fix plate in medial position i.e., tension side of the bone. Anatomical dissection was carried out where muscle bellies, tendon, arteries and veins were not cut during the operation. The muscle bellies of fibularis longus and gastrocnemius were pulled apart in opposite direction to expose the fractured fragments. Hematoma from fractured site was cleaned with normal saline lavage. Fractured fragments were reduced manually with traction and counter traction. Open reduction and rigid internal fixation were done with 2.7mm veterinary cuttable plate in group I and locking reconstruction plate in group II. As per AO principle in both the groups bone plates were fixed. The screw selected were optimum and provided rigid fixation. In both groups bridging plate osteosynthesis of bone plating was performed. Suture material and pattern used were satisfactory in closure of muscle and skin in both groups. Intra-operative difficulties were not observed in fixation of bone plate.

4.9 POST-OPERATIVE CARE

The post-operative dressing of sutured wound was done with light weight sterile gauze bandage which provided even pressure throughout the length of the operated leg and there by prevented the wound from the oedema, self-mutilation, external injury and helped in early healing by controlling wound contamination. Skin sutures were removed on 7^{th} to 14^{th} post-operative day in all birds after wound healing. However, 1 bird in each group had wound dehiscence on 6^{th} post-operative day in group I and 12^{th} post-operative day in group II. The cause for wound dehiscence might be due to intimate contact of skin with bone plate at distal part in medial aspect of leg and absence of muscular covering over the plate.

Post-operative administration of enrofloxacin for 5 days and meloxicam for 3 days controlled post-operative infection and inflammation in birds of both the group. However, each bird in both the groups had wound infection from 6th post-operative day in group I and 12th post-operative day in group II. Later with regular antiseptic dressing in these 2 birds wound healed by secondary intension on 14th post-operative day in group I bird and 30th post-operative day in group II bird.

In both the groups supportive oral calcium (for 14 days) and multivitamin supplements (for 7 days) helped early healing of fracture and wound of operated leg. In addition to oral supplementation physiotherapy of operated leg was done on alternate days till 14th post-operative day. Which prevented muscular spasticity and joint rigidity there by all the birds in both the groups had early ambulation of the operated leg.

4.10 EVALUATION OF STUDY

4.10.1 Clinical evaluation

Clinical evaluation of operated birds was observed till recovery. The observations recorded were swelling, weight bearing, gait and wound healing at different intervals pre-operatively, day 0, 7th, 14th, 30th, 45th and 60th post-operative days in both groups.

4.10.1.1 Swelling

In birds of the both the group had post-operative swelling of operated leg from day 0. However, swelling was gradually decreased in birds of both the groups up to 7th post-operative day as shown in plate 23 and 24.

The reason was due to open reduction and internal fixation of plate and handling of soft tissue resulted in post-operative inflammatory swelling.

4.10.1.2 Weight bearing

The weight bearing in all the birds were graded as full weight bearing (excellent), slight lameness after exercise (good), slight to moderate lameness and consistency of weight bearing (fair) and intermittent or consistent non-weight bearing and lameness (poor) as per the technique recommended by Fox *et al*. (1995) the results were shown in Table 7 and 8.

4.10.1.2.1 Weight bearing in birds treated using veterinary cuttable plates (group I)

In group I, all birds showed poor weight bearing on pre-operative and post-operative day 0. All the birds beared the weight by sitting on hock with fractured leg (plate 25) and operated leg as shown in plate 26.

On 7th post-operative day, 1 bird showed good weight bearing (plate 27), 4 birds fair weight bearing and 1 bird poor weight bearing while standing and walking.

On 14th post-operative day, 5 birds showed improvement in weight bearing from fair to good (plate 28) and 1 bird showed fair weight bearing in standing and walking.

On 30th post-operative day, 3 birds showed excellent weight bearing in standing and walking whereas remaining 3 birds showed good weight bearing (plate 29) in standing and walking.

On 45th post-operative day, 4 birds showed excellent weight bearing in standing and walking (plate 30). However, 2 birds showed only good weight bearing in standing and walking. Because 1 bird had mal-alignment of fractured fragments and another bird had mal-alignment with screw pull out.

On 60th post-operative day, 5 birds showed excellent weight bearing in standing and walking (plate 31). However, 1 bird showed only good weight bearing in standing and walking because of mal-alignment of fractured fragments and screw pull out.

4.10.1.2.2 Weight bearing in birds treated using locking reconstruction plates (group II)

In group II, all birds had poor weight bearing on pre-operative and post-operative day 0. All the birds were sitting on hock with fractured leg (plate 32) and unable to bear weight on operated leg as shown in plate 33.

On 7th post-operative day, 1 bird had good weight bearing (plate 34) and 5 birds fair weight bearing while standing and walking.

On 14th post-operative day, 5 birds showed improvement in weight bearing from fair to good (plate 35) and 1 bird showed fair weight bearing in standing and walking.

On 30th post-operative day, 4 birds showed excellent weight bearing (plate 36) and 2 birds showed good weight bearing in standing and walking.

On 45th post-operative day, 5 birds showed excellent weight bearing in standing and walking (plate 37). However, 1 bird showed only good weight bearing in standing and walking because the bird had wound at distal end of operated leg.

On 60th post-operative day, all birds showed excellent weight bearing in standing and walking (plate 38)

In both the groups birds showed improvement from pre-operative day with poor to excellent weight beating on 60th post-operative day. However, on 60th post-operative day in group I, 1 bird did not show improvement in weight bearing from good to excellent. Whereas, in group II birds all birds showed improvement to excellent in weight bearing. The birds when compared between the group the weight bearing was better in group II birds on 30th and 45th interval than group I birds and other intervals it was almost similar.

4.10.1.3 Lameness score

The lameness grading of the operated leg in birds was evaluated for lameness score as mentioned by Kestin *et al.* (1992) as showed in Table 3.

Evaluation of operated leg in birds for lameness score was done pre-operatively, immediately after surgery on day 0, 7th, 14th, 30th, 45th and 60th post-operative days in both groups.

4.10.1.3.1 Veterinary cuttable plate (Group I)

In group I birds average lameness score pre-operative, day 0, 7th, 14th, 30th, 45th and 60th post-operative day were 5.00, 5.00, 3.16, 2.50, 1.00, 0.66 and 0.33 respectively.

Within the group average lameness score showed improvement from pre-operative to 60th post-operative day indicated healing of fracture and returning to normal function of leg.

4.10.1.3.2 Locking Reconstruction Plate (group II)

In group II birds average lameness score pre-operative, day 0, 7th, 14th, 30th, 45th and 60th post-operative day were 5.00, 5.00, 2.83, 2.16, 0.66, 0.33 and 0.00 respectively.

Within the group average lameness score showed improvement from pre-operative to 60th post-operative day indicated healing of fracture and returning to normal function of leg.

When compared in between the groups the average lameness score showed similar on pre-operative and day 0. However, the average lameness score in group II birds showed better on 7th, 14th, 30th, 45th and 60th post-operative days when compared to group I birds.

4.10.1.4 Wound healing

In the birds of both the groups first intension healing of wound was observed. The sutures were removed on 7th to 14th post-operative day in both the group of birds. However, each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6th and 12th post-operative days of group I and group II respectively. Because close proximity of plate and skin and also absence of muscle mass at distal end of operated leg. However, wound healed by second intension healing on 14th day and 45th day respectively.

Greenish discoluration of skin on medial aspect of operated leg (plate 39 and 40) was observed in 3 birds of group I and 2 birds of group II. The greenish discoluration might be due to tissue response to external injury. However, the greenish discolouration returned to normal gradually from day of operation to 7th post-operative day in both the group of birds.

4.10.2 Radiological Evaluation

The radiological scoring of the operated leg was evaluated for fracture healing with radiological scoring system suggested by Tunio *et al*. (2014) as showed in Table 4.

Radiological evaluation of operated leg in birds for fracture healing with radiological scoring was done immediately after surgery on day 0, 7th, 14th, 30th, 45th and 60th post-operative days in both groups.

4.10.2 Radiological scoring system

4.10.2.1 Fracture line

4.10.2.1.1 Veterinary Cuttable Plate (Group I)

The mean values of fracture line in group I on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 0.00±0.00, 1.00±0.00, 1.67±0.21, 2.00±0.00 and 2.00±0.00 respectively. The values were presented in Fig.1 and Table 9.

In all the birds of group I, fracture line was visible on day 0 (plate 41 and 42) and 7th post-operative day (plate 43 and 44) and partially visible on 14th post-operative day (plate 45 and 46). Whereas on 30th, 45th and 60th post-operative day fracture line was absent.

Suggestive of complete union of fracture fragments as shown in plate 47, 48, 49, 50, 51 and 52.

4.10.2.1.2 Locking Reconstruction Plate (Group II)

The mean values of fracture line in group II on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 0.00±0.00, 0.83±0.17, 1.67±0.21, 2.00±0.00 and 2.00±0.00 respectively. The values were presented in Fig.1 and Table 9.

In group II, all the birds showed similar findings with respect to visibility of fracture line as that of group I birds as shown in plate 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63 and 64.

In both the groups fracture line was absent on day 0 and 7th post-operative day. Partially visible on 14th post-operative day. Absent on 30th, 45th and 60th post-operative day.

No significant difference was observed when compared between the groups with respect to fracture line.

4.10.2.2 Callus Formation

4.10.2.2.1 Veterinary Cuttable Plate (Group I)

The mean values of callus formation in group I on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 0.83±0.16, 1.00±0.00, 1.00±0.00, 1.00±0.00 and 1.00±0.00 respectively. The values were presented in Fig.2 and Table 10.

In all the birds of group I, no callus formation was observed on day 0 (plate 41 and 42). However, from 7th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds (plate 43, 44, 45, 46, 47 and 48). Whereas on 45th and 60th post-operative day remodelling of callus was observed. Suggestive of primary healing of fracture fragments in birds as shown in plate 49, 50, 51 and 52.

In group I birds, 1bird showed slight bending of plate on 7th post-operative day and in another 2 birds showed mal-alignment of fractured fragment on 7th post-operative day. The reason was only 1 proximal screw pull out and fixation of only 2 screws in upper fragment where as in another bird a small piece of bone fragment came out of alignment. However, in all these birds fracture healed completely.

4.10.2.2.2 Locking Reconstruction Plate (group II)

The mean values of callus formation in group II on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 0.00±0.00, 1.00±0.00, 1.00±0.00, 1.00±0.00 and 1.00±0.00 respectively. The values were presented in Fig.2 and Table 10.

In all the birds of group II, no callus formation was observed on day 0 and 7th post-operative day (plate 53, 54, 55 and 56). However, from 14th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds (plate 57, 58, 59 and 60). Whereas on 45th and 60th post-operative day remodelling of callus was observed. Suggestive of primary healing of fracture fragments in birds as shown in plate 61, 62, 63 and 64.

In group II birds, use of locking reconstruction plate complications like mal-alignment of fracture fragments, bending of plate and pull out of screws were not observed.

In between the groups with respect to callus formation no significant difference was observed at all intervals of the study.

4.10.2.3 Bone Union

4.10.2.3.1 Veterinary cuttable plate (group I)

The mean values of bone union in group I on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 2.00±0.00, 2.00±0.00, 2.00±0.00, 2.00±0.00 and 2.00±0.00 respectively. The values were presented in Fig. 3 and Table 11.

In group I birds, on day 0 bone union was not observed (plate 41 and 42). However, from 7th post-operative day to 60th post-operative day progressive healing of fracture with minimum callus formation and union of fracture fragments were observed with remodelling of callus and continuation of medullary canal suggestive of primary healing (plate 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52). In 2 birds of group I, showed mal-alignment of fracture fragments with callus formation leading to union of fracture fragments.

4.10.2.3.2 Locking Reconstruction Plate (Group II)

The mean values of bone union in group II on day 0, 7th, 14th, 30th, 45th and 60th post-operative days were 0.00±0.00, 0.00±0.00, 2.00±0.00, 2.00±0.00, 2.00±0.00 and 2.00±0.00 respectively. The values were presented in Fig. 3 and Table 11.

In group II birds, on day 0 and 7th post-operative day bone union was not observed (plate 53, 54, 55 and 56). However, from 14th post-operative day to 60th post-operative day progressive healing of fracture with minimum callus formation and union of fracture fragments were observed with remodelling of callus and continuation of medullary canal suggestive of primary healing as shown in plate 57, 58, 59, 60, 61, 62, 63 and 64.

In between the groups with respect to bone union no significant difference was observed.

4.10.3 Computed Tomographic Evaluation

In both the groups computed tomographic evaluation of fracture healing was done on 7th 14th 30th post-operative days.

3-dimentional view of cranio-caudal, latero-medial and longitudinal sagittal section of repaired tibiotarsus bone with plating was evaluated in respective intervals.

In both the groups 3-dimentional view showed presence of fracture line on 7th post-operative day, partially visible on 14th post-operative day and complete absence on 30th post-operative day suggestive of primary healing of fracture. The fracture healing was also supported by longitudinal sagittal view with similar trend of fracture healing as shown in plate 65, 66, 67, 68, 69 and 70.

There was no difference in fracture healing when compared between the groups.

The computed tomography at different interval supported the radiographic finding at corresponding intervals and it helped in viewing the fracture healing in all dimensions of bone and also the implant fixation with bone fragments.

4.11 COMPLICATIONS

In both the group of birds complications were recorded during the study period.

In group I, 2 birds had implant related post-operative complications. In 1 bird slight bending of plate was observed at diaphyseal region of fracture (plate 71). However, implant was stable enough to bear the weight of the leg. On 60^{th} post-operative day complete healing of fracture was observed along with bending of plate (plate 71). In another bird proximal screw pull out was observed on 7^{th} post-operative day (plate 72) and it maintained till healing of the bone.

In group II birds no implant related complications were observed.

Each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6^{th} and 12^{th} post-operative days of group I (plate 73) and group II (plate 74) respectively. Because close proximity of plate and skin and also absence of muscle mass at distal end of operated leg. Both the birds wound healed by second intension on 14^{th} (plate 73) and 45^{th} day (plate 74) respectively.

Table 5: Signalment recorded in birds for repair of tibiotarsus fracture in group I and II

Group	Bird No.	Sex	Body weight (kg)	Limb involved	Bone involved	Type of fracture		
I	1	Female	1.37	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	2	Male	1.47	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	3	Male	1.39	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	4	Female	1.39	Right	Tibiotarsus	Simple	Proximal-metaphyseal	Transverse
	5	Male	1.41	Right	Tibiotarsus	Simple	Distal-metaphyseal	Oblique
	6	Female	1.33	Right	Tibiotarsus	Simple	Diaphyseal	Communiated
		Male=3 Female=3	1.39±0.02	Right=6	Tibiotarsus=6	Simple=6	Diaphyseal=4 Proximal-metaphyseal-1 Distal-metaphyseal=1	Oblique=4 Transverse=1 Communiated=1
II	1	Male	1.27	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	2	Male	1.44	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	3	Female	1.47	Right	Tibiotarsus	Simple	Metaphyseal	Transverse
	4	Female	1.38	Right	Tibiotarsus	Simple	Diaphyseal	Oblique
	5	Male	1.49	Right	Tibiotarsus	Simple	Diaphyseal	Oblique-communicated
	6	Female	1.25	Right	Tibiotarsus	Simple	Diaphyseal	Transverse
		Male=3 Female=3	1.38±0.04	Right=6	Tibiotarsus=6	Simple=6	Diaphyseal=5 Metaphyseal=1	Oblique=3 Transverse=2 Oblique-communiated=1

Table 6: Details of implant used for tibiotarsus fracture repair in Aseel birds of both the groups

Group	Bird No.	Length of the bone (cm)	Width of the bone (mm)		Implant size	No. of holes purchased with screws	Length of the screws used
			Proximal	Distal			
I	1	11.7	10	8.6	2.7mm 10 holes	6	(18mm, 2) (16mm, 4)
	2	14.1	13	12	2.7mm 10 holes	8	(18mm, 3) (16mm, 5)
	3	13.7	11	9.7	2.7mm 10 holes	8	(16mm, 8)
	4	14.1	13	11	2.7mm 10 holes	9	(18mm, 4) (16mm, 5)
	5	12.6	12	11	2.7mm 10 holes	8	(18mm, 5) (16mm, 3)
	6	13.3	13	12	2.7mm 10 holes	7	(18mm, 6) (16mm, 1)
		13.25±0.38	12.00±0.51	10.77±0.54	2.7mm 10 holes=6	6=1,7=1, 8=3,9=1	18mm=20, 16mm=26
II	1	12.6	12	11	2.7mm 10 holes	9	(18mm, 1) (16mm, 8)
	2	14.3	12	10	2.7mm 12 holes	10	(18mm, 8) (16mm, 2)
	3	14.1	12	11	2.7mm 10 holes	9	(18mm, 3) (16mm, 6)
	4	12.9	11	10	2.7mm 10 holes	9	(18mm, 4) (16mm, 5)
	5	12.6	12	10	2.7mm 10 holes	9	(18mm, 5) (16mm, 4)
	6	11.8	11	10	2.7mm 10 holes	9	(18mm, 3) (16mm, 6)
		13.05±0.39	11.60±0.21	10.33±0.21	2.7mm 10 holes=11 2.7mm 12 holes=1	9=5,10=1	18mm=24, 16mm=31

Table 7: Weight bearing score in birds of group I treated with veterinary cuttable plate

Bird No.	Pre-operative	Day 0	7th Day	14th Day	30th Day	45th Day	60th Day
1	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
2	Poor	Poor	Fair	Good	Good	Good	Good
3	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
4	Poor	Poor	Fair	Good	Good	Excellent	Excellent
5	Poor	Poor	Good	Good	Excellent	Excellent	Excellent
6	Poor	Poor	Poor	Fair	Good	Good	Excellent
Total	Poor=6	Poor=6	Good=1 Fair=4 Poor=1	Good=5 Fair=1	Excellent=3 Good=3	Excellent=4 Good=2	Excellent=5 Good=1

Excellent: Full weight bearing
Good: Slight lameness after exercise
Fair: Slight to moderate lameness and consistency of weight bearing
Poor: Intermittent or consistent non-weight bearing and lameness

Table 8: Weight bearing score in birds of group II treated with locking reconstruction Plate

Bird No.	Pre-operative	Day 0	7th Day	14th Day	30th Day	45th Day	60th Day
1	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
2	Poor	Poor	Fair	Good	Good	Excellent	Excellent
3	Poor	Poor	Good	Good	Excellent	Excellent	Excellent
4	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
5	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
6	Poor	Poor	Fair	Fair	Good	Good	Excellent
Total	Poor=6	Poor=6	Good=1 Fair=5	Good=5 Fair=1	Excellent=4 Good=2	Excellent=5 Good=1	Excellent=6

Excellent: Full weight bearing
Good: Slight lameness after exercise
Fair: Slight to moderate lameness and consistency of weight bearing
Poor: Intermittent or consistent non-weight bearing and lameness

Table 9: Mean ± SE of fracture line in tibiotarsus bone of birds in group I and II

Groups	Day 0	7th Day	14th Day	30th Day	45th Day	60th Day
I	0.00±0.00	0.00±0.00	1.00±0.00	1.67±0.21	2.00±0.00	2.00±0.00
II	0.00±0.00	0.00±0.00	0.833±0.17	1.67±0.21	2.00±0.00	2.00±0.00

Table 10: Mean ± SE of callus formation in tibiotarsus bone of birds in group I and II

Groups	Day 0	7th Day	14th Day	30th Day	45th Day	60th Day
I	0.00±0.00	0.83±0.16	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00
II	0.00±0.00	0.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00	1.00±0.00

Table 11: Mean ± SE of bone union in tibiotarsus bone of birds in group I and II

Groups	Day 0	7th Day	14th Day	30th Day	45th Day	60th Day
I	0.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00
II	0.00±0.00	0.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00	2.00±0.00

Figure 1: Mean± SE of fracture line in tibiotarsus bone of Aseel birds in group I and II

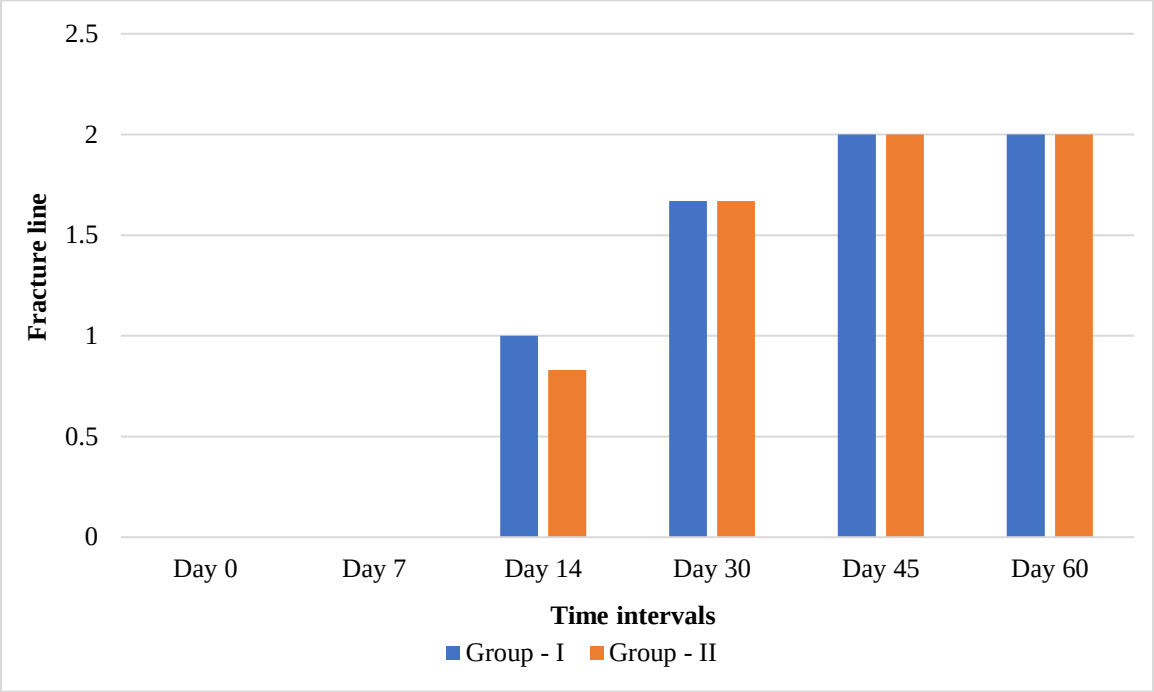


Figure 2: Mean ± SE of callus formation in tibiotarsus bone of Aseel birds in group I and group II

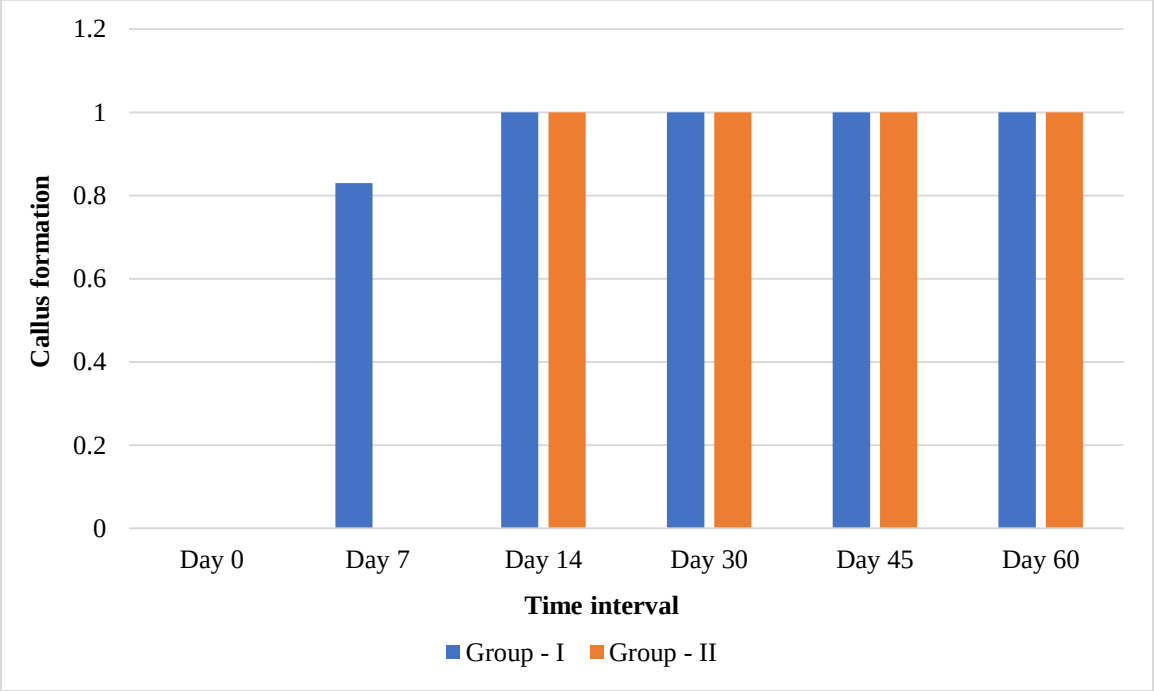
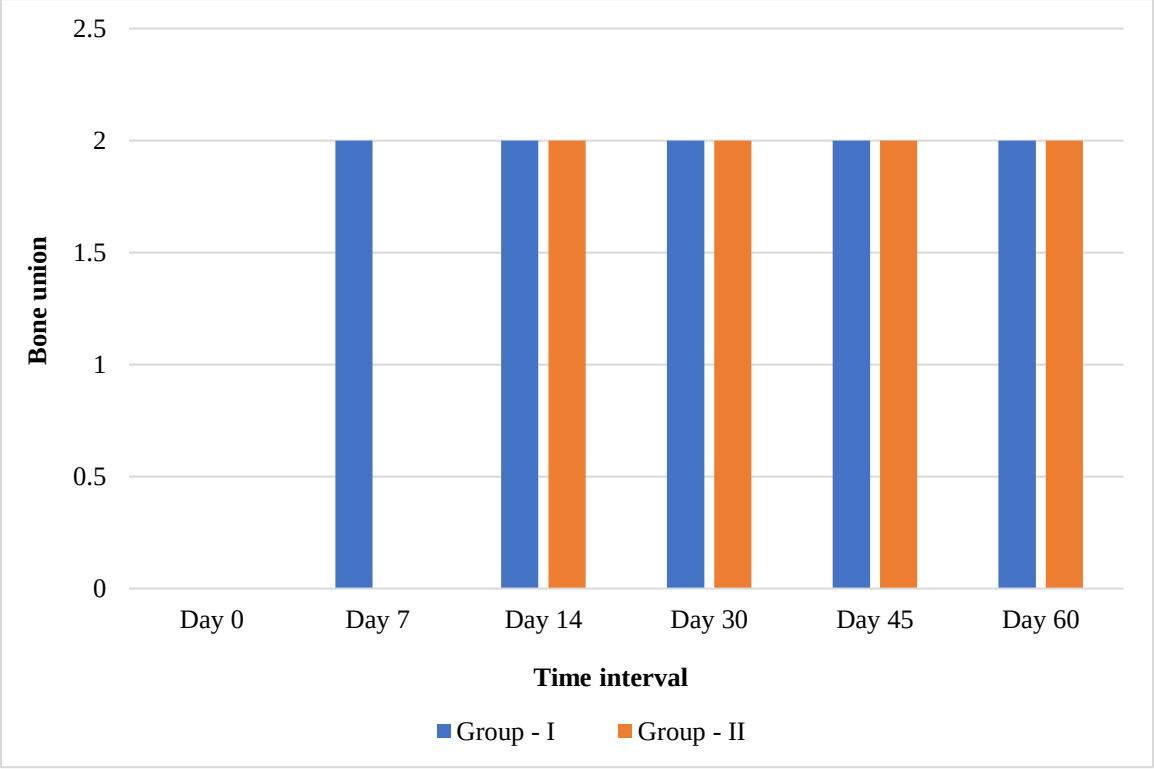


Figure 3: Mean± SE of bone union in tibiotarsus bone of Aseel birds in group I and group II



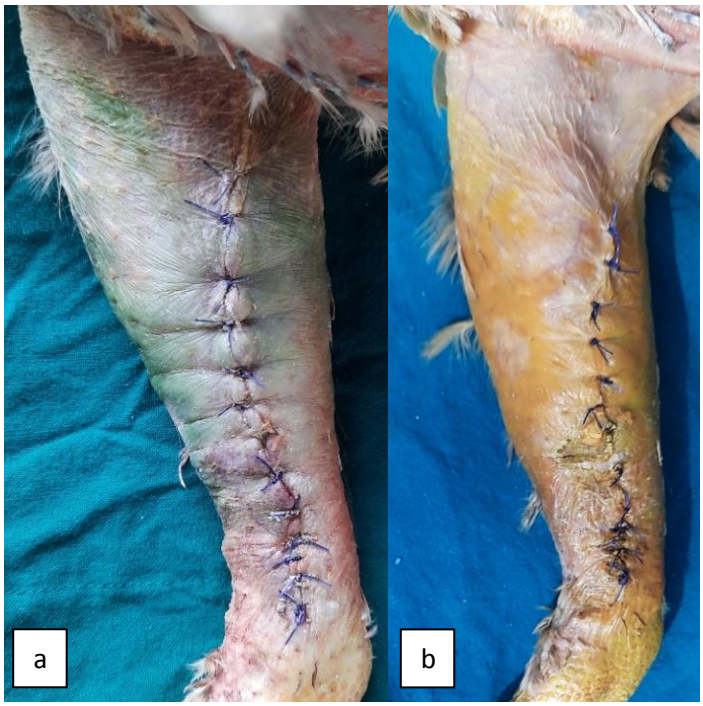


Plate 23: Photograph showing (a) swelling of right leg on 2nd post-operative Day (b) reduction of swelling on 7th post-operative day in a bird of group I

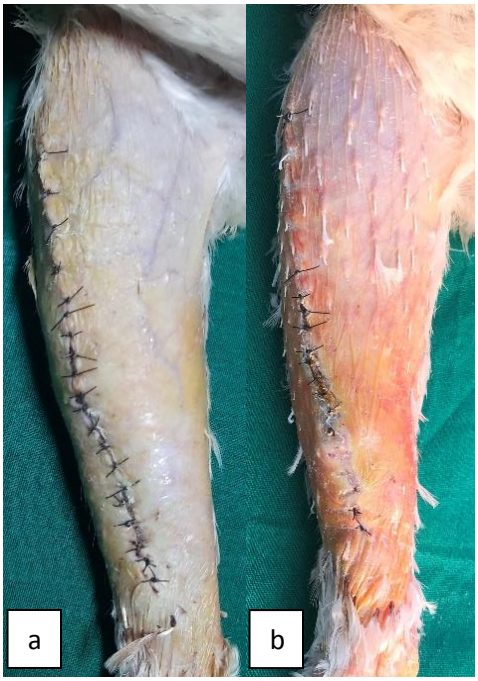


Plate 24: Photograph showing (a) swelling of right leg on 2nd post-operative day and (b) reduction in swelling on 7th post-operative day in a bird of group II

Plate 25: Photograph showing poor weight bearing on fractured right leg before operation in a bird of group I

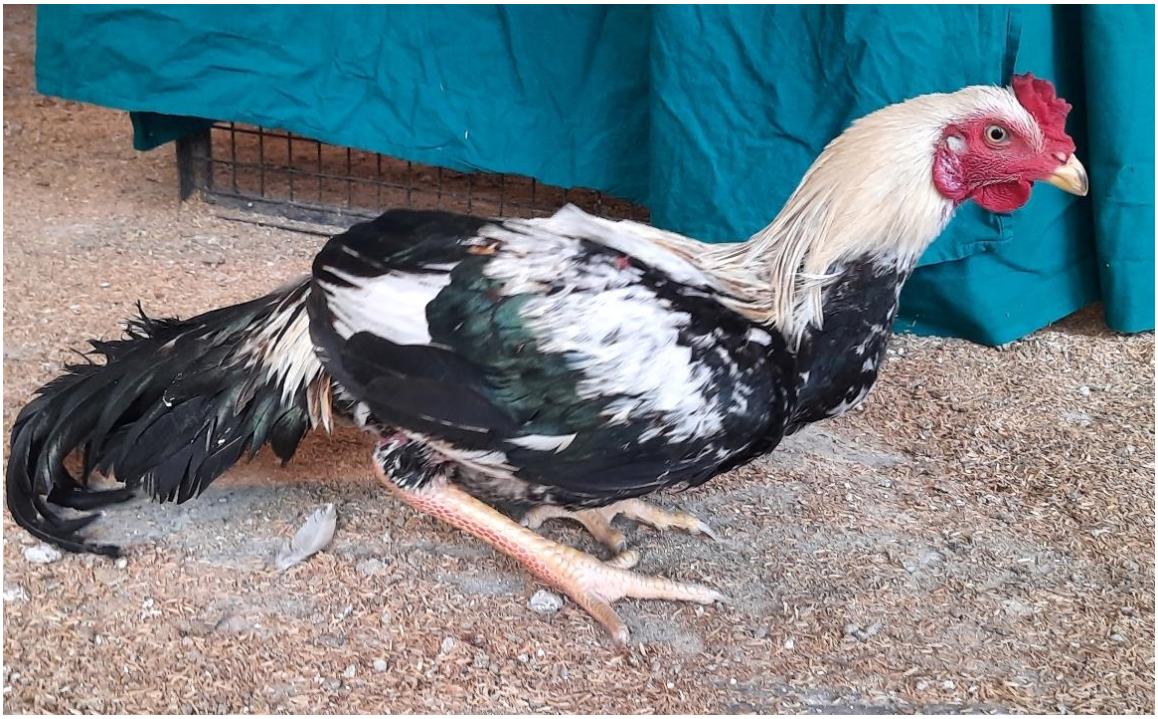


Plate 26: Photograph showing poor weight bearing on right leg repaired with veterinary cuttable plate after operation on day 0 in a bird of group I

Plate 27: Photograph showing good weight bearing on right leg repaired with veterinary cuttable plate on 7th-post operative day in a bird of group I

Plate 28: Photograph showing good weight bearing on right leg repaired with veterinary cuttable plate on 14th post-operative day in a bird of group I

Plate 29: Photograph showing good weight bearing on right leg repaired with veterinary cuttable plate on 30th post-operative day in a bird of group I

Plate 30: Photograph showing excellent weight bearing on right leg repaired with veterinary cuttable plate on 45th post-operative day in a bird of group I

Plate 31: Photograph showing excellent weight bearing on right leg repaired with veterinary cuttable plate on 60th post-operative day in a bird of group I

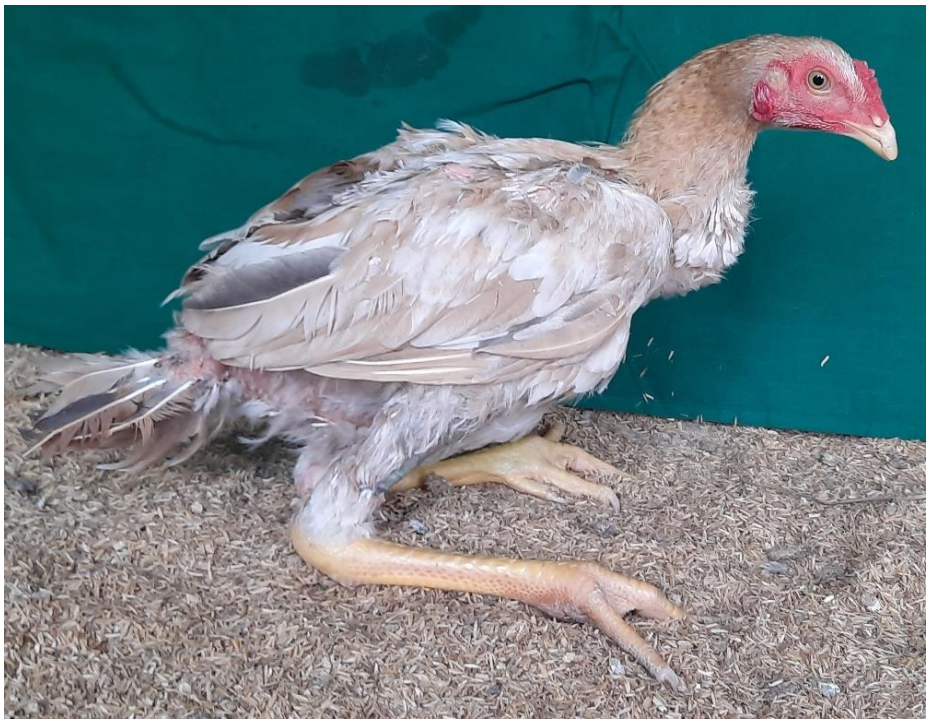


Plate 32: Photograph showing poor weight bearing on fractured right leg before operation in a bird of group II

Plate 33: Photograph showing poor weight bearing on right leg repaired with locking reconstruction plate after operation on day 0 in a bird of group II

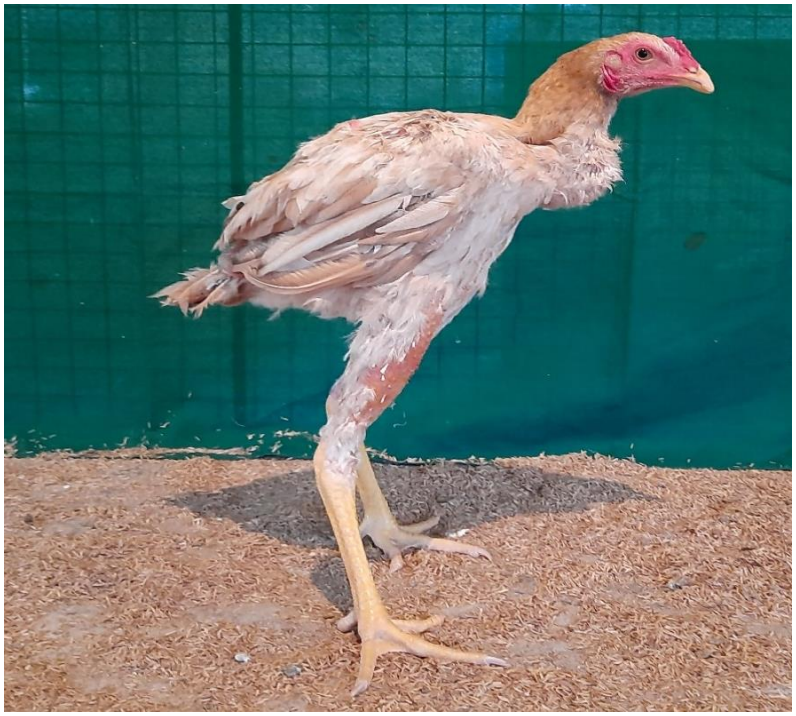


Plate 34: Photograph showing good weight bearing on right leg repaired with locking reconstruction plate on 7th post-operative day in a bird of group II

Plate 35: Photograph showing good weight bearing on right leg repaired with locking reconstruction plate on 14th post-operative day in a bird of group II

Plate 36: Photograph showing excellent weight bearing on right leg repaired with locking reconstruction plate on 30th post-operative day in a bird of group II

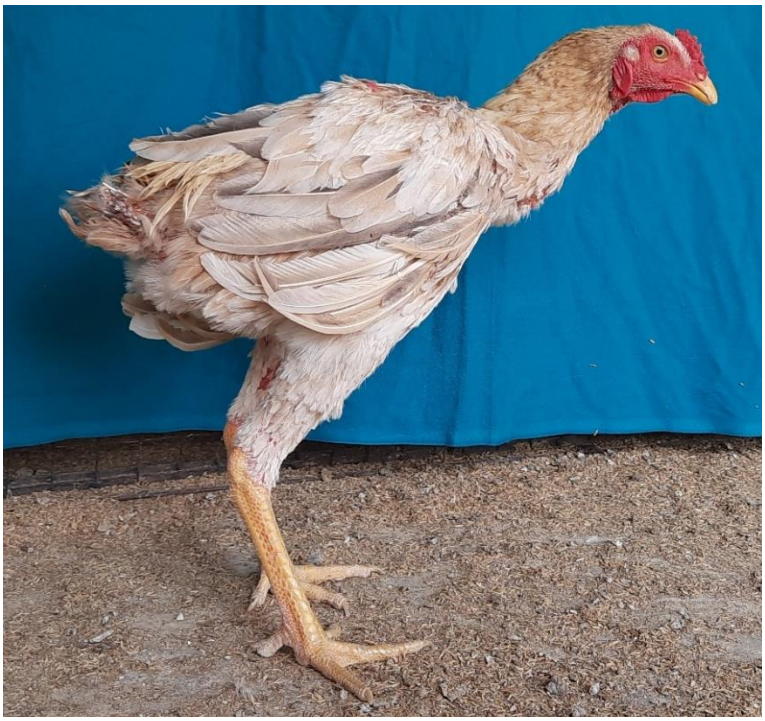


Plate 37: Photograph showing excellent weight bearing on right leg repaired with locking reconstruction plate on 45th post-operative day in a bird of group II

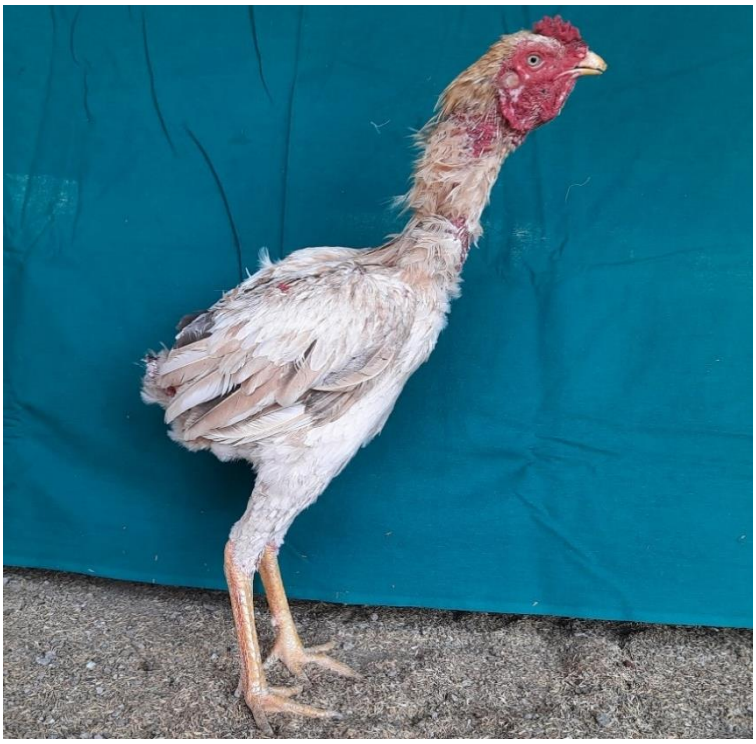


Plate 38: Photograph showing excellent weight bearing on right leg repaired with locking reconstruction plate on 60th post-operative day in a bird of group II

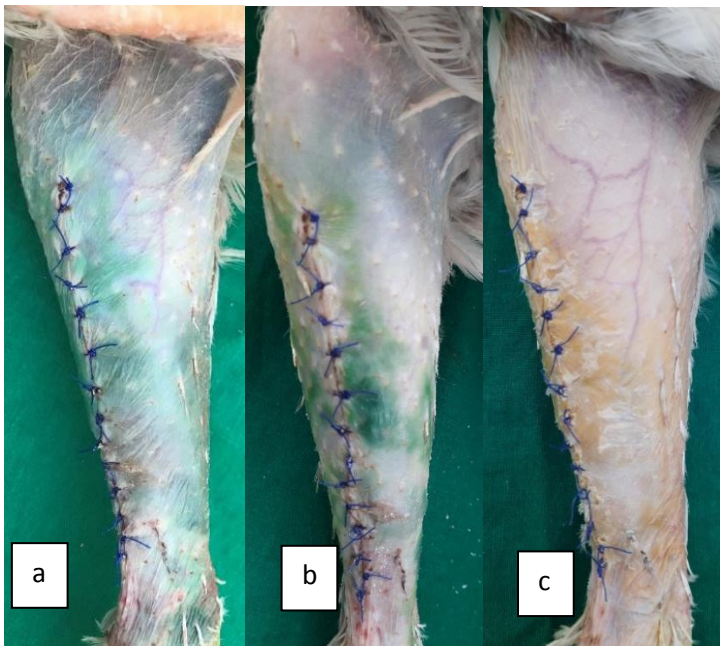


Plate 39: Photograph showing (a) greenish discolouration of skin around the suture line, extending from stifle joint to hock joint on 2nd post-operative day, (b) reduction in greenish discolouration of skin on 4th day post-operative day and c) appearance of normal skin colour on 7th post-operative day in a bird of group I

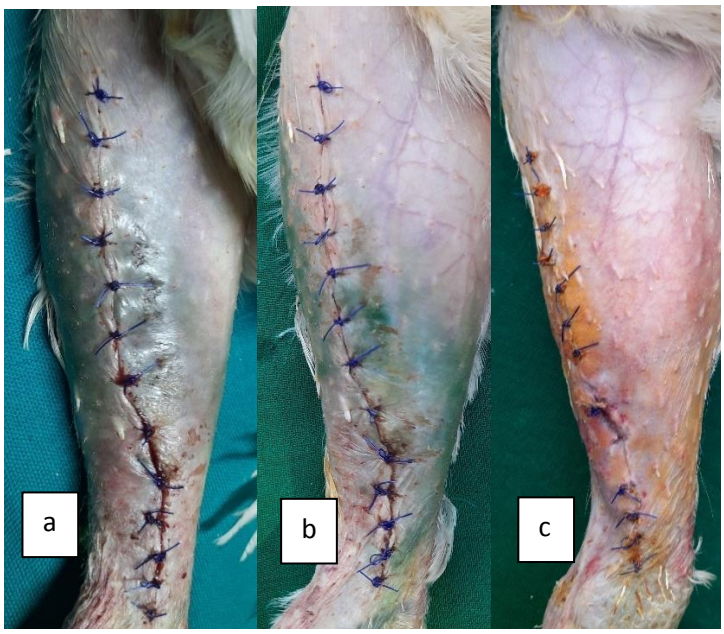


Plate 40: Photograph showing (a) greenish discolouration of skin around the suture line extending from stifle joint to hock joint in a bird of group II on 2nd post-operative day, (b) reduction in greenish discolouration of skin 4th post-operative day in a bird of group II (b), (c) appearance of normal skin colour on 7th post-operative day in a bird of group II

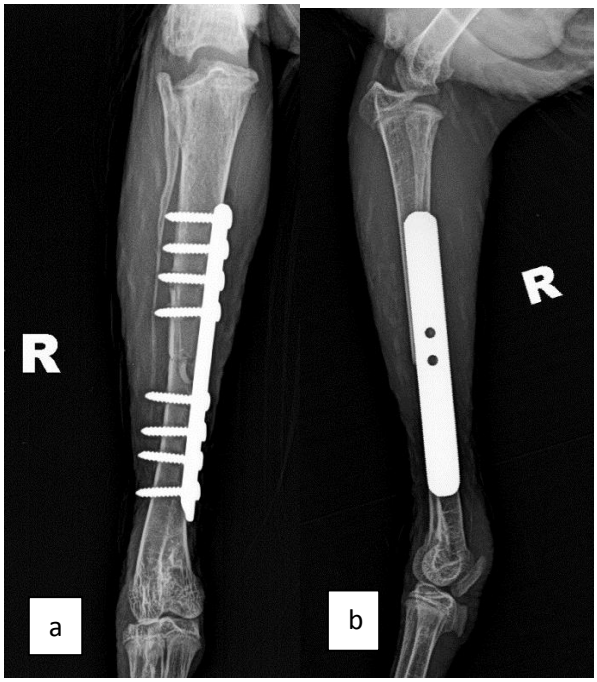


Plate 41: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing anatomical apposition of fractured fragments and presence of fractured line of a tibiotarsus bone after repair with veterinary cuttable plate in a bird of group I (post-operative day 0)

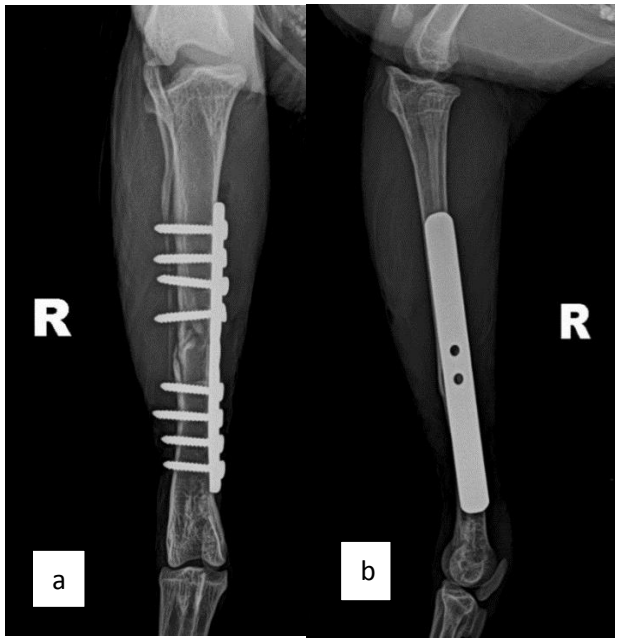


Plate 42: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing anatomical apposition of fractured fragments and presence of fracture line of a tibiotarsus bone after repair with veterinary cuttable plate in a bird of group I (post-operative day 0)

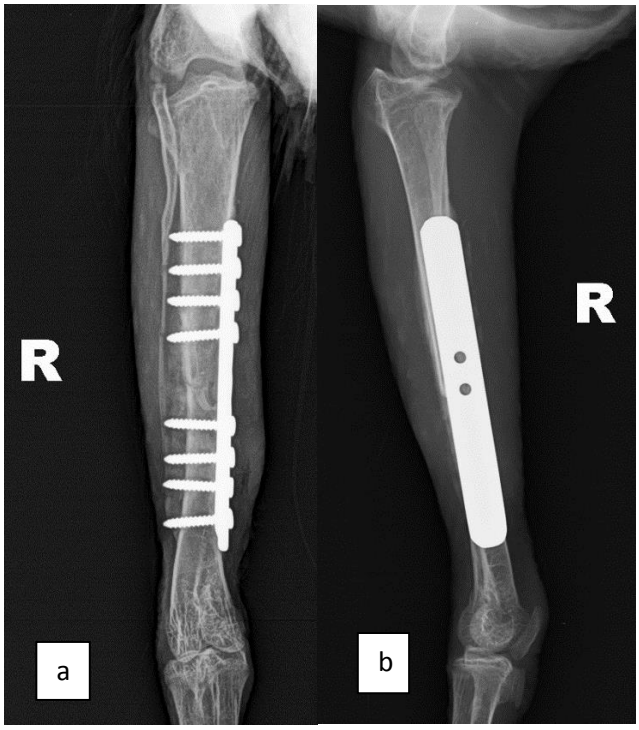


Plate 43: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing visible fracture line and minimal callus formation around the fracture site in a tibiotarsus bone after repair with veterinary cuttable plate in a bird of group I (7th post-operative day)

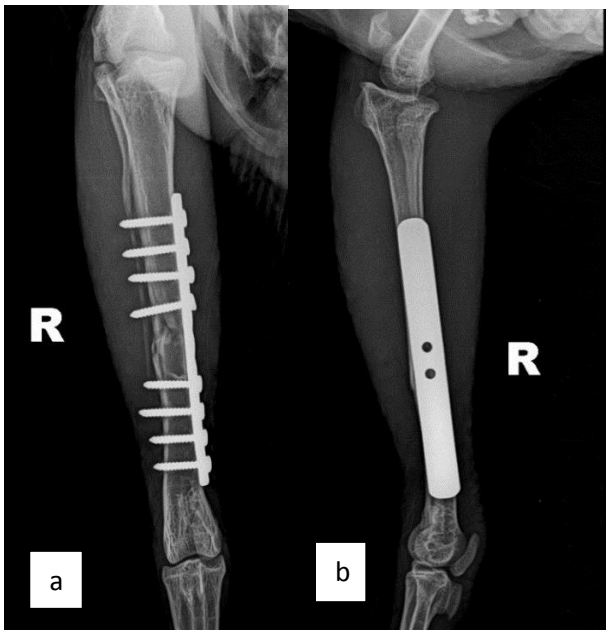


Plate 44: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing visible fracture line and minimal callus formation around the fracture site in a tibiotarsus bone after repair with veterinary cuttable plate in a bird of group I (7th post-operative day)

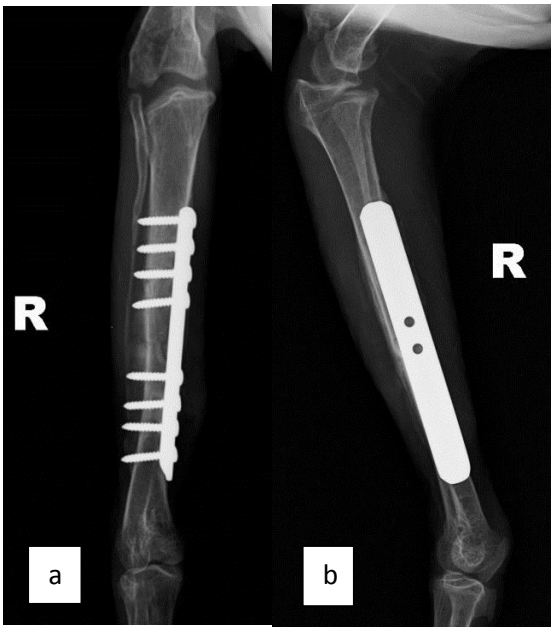


Plate 45: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing union of fractured fragments, minimal callus formation with partial visualisation of fracture line of a tibiotarsus bone repaired with veterinary cuttable plate in a bird of group I (14th post-operative day)

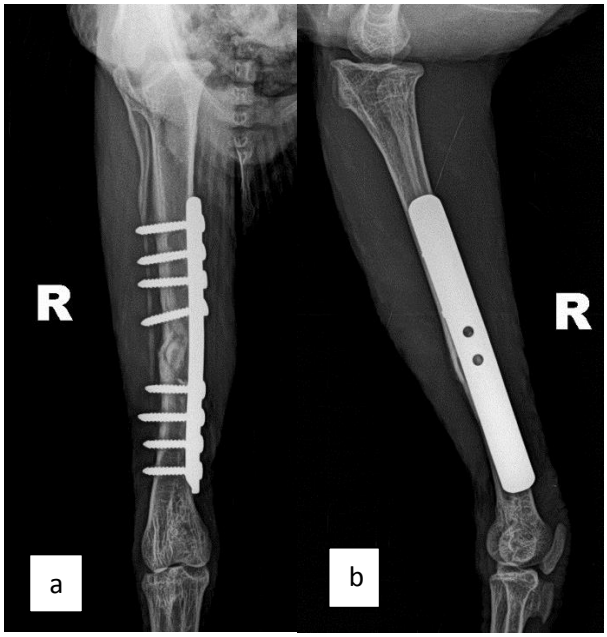


Plate 46: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing union of fractured fragments, minimal callus formation with partial visualisation of fracture line of a tibiotarsus bone repaired with veterinary cuttable plate in a bird of group I (14th post-operative day)

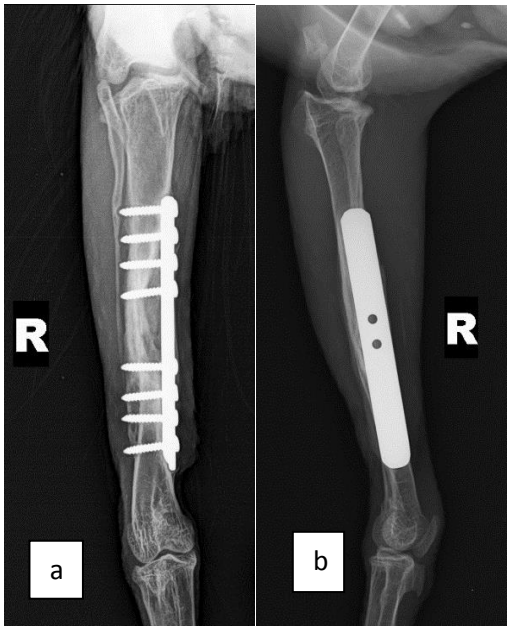


Plate 47: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation with absence of fracture line of a tibiotarsus bone repaired with veterinary cuttable plate in a bird of group I (30th postoperative day)

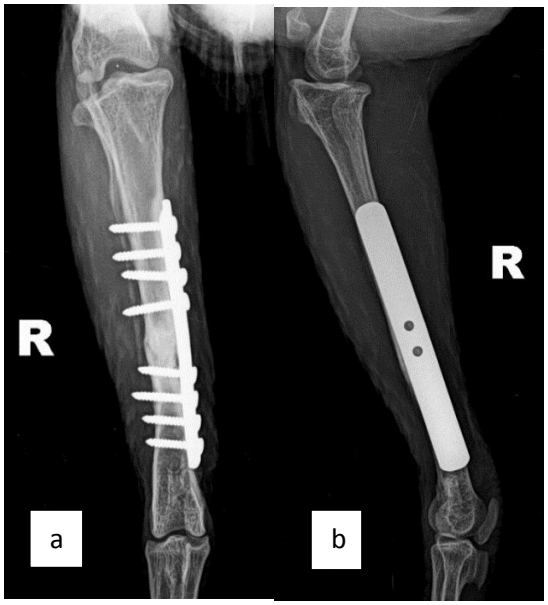


Plate 48: Cranio-caudal (b) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation with absence of fracture line of a tibiotarsus bone repaired with veterinary cuttable plate in a bird of group I (30th post-operative day)

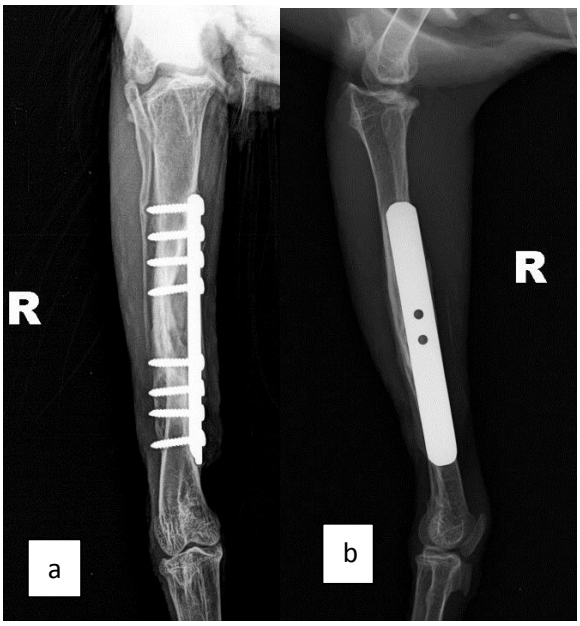


Plate 49: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodelling of fracture line of a tibiotarsus bone after repaired with veterinary cuttable plate in a bird of group I (45th post-operative day)

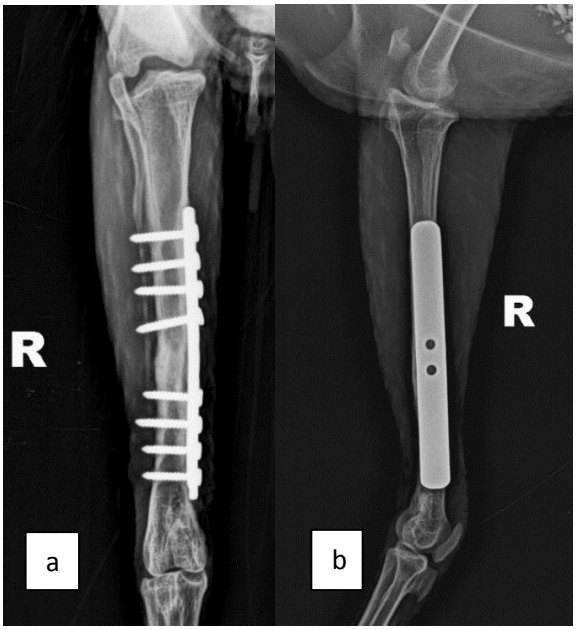


Plate 50: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodelling of fracture line of a tibiotarsus bone after repaired with veterinary cuttable plate in a of group I (45th post-operative day)

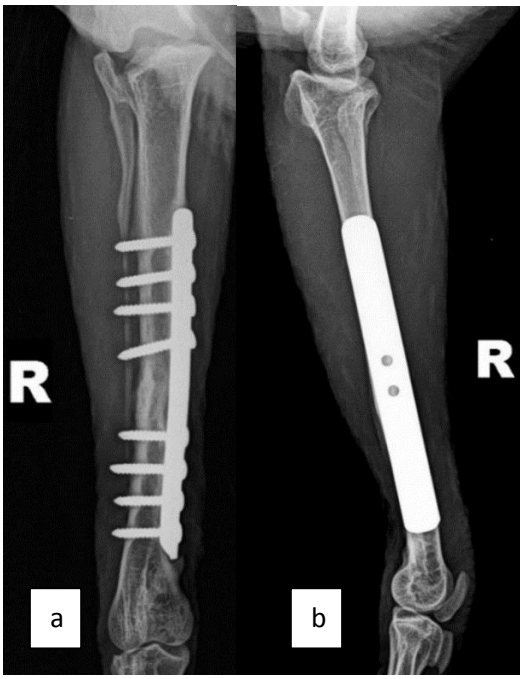


Plate 51: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodelling of fracture line of a tibiotarsus bone after repaired with veterinary cuttable plate in a bird of group I (60th post-operative day)

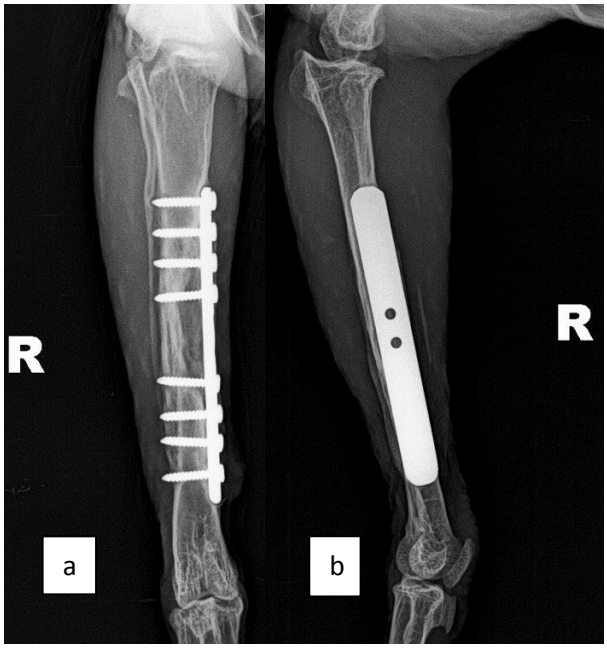


Plate 52: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodelling of fracture line of a tibiotarsus bone after repaired with veterinary cuttable plate in a bird of group I (60th post-operative day)

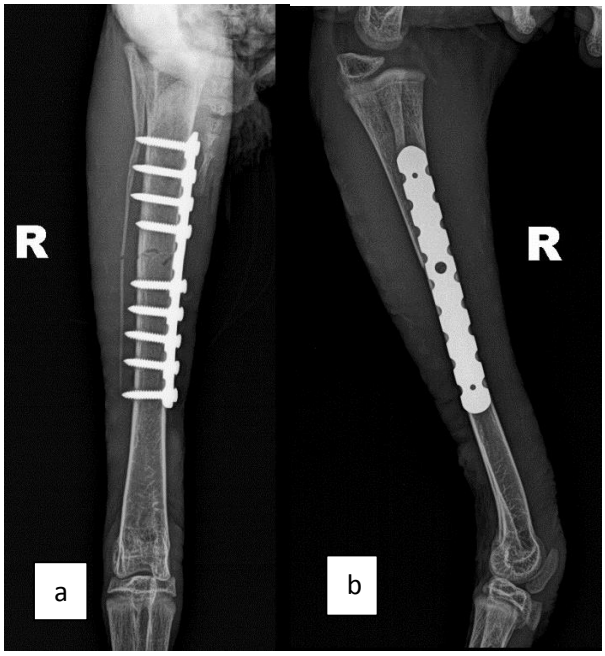


Plate 53: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing anatomical apposition of fractured fragments and presence of fracture line of a tibiotarsus bone after repair with locking reconstruction plate in a bird of group II (post-operative day 0)

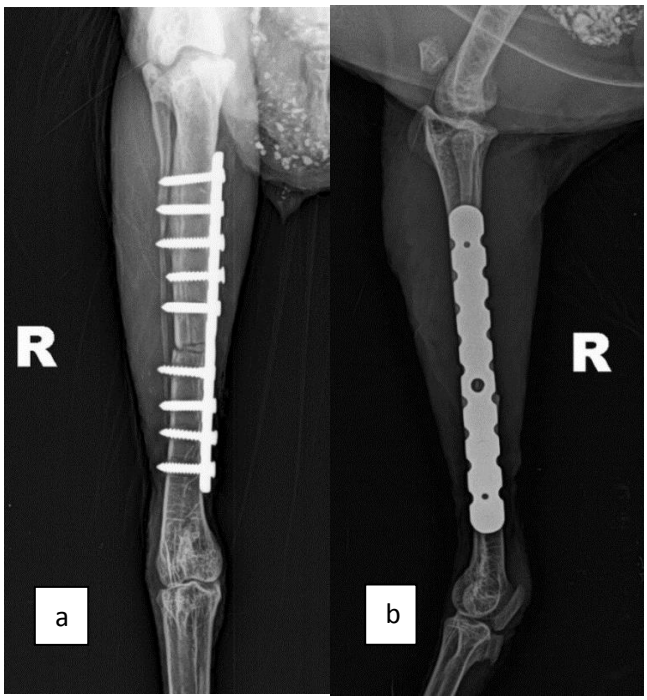


Plate 54: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing anatomical apposition of fractured fragments and presence of fracture line of a tibiotarsus bone after repair with locking reconstruction plate in a bird of group II (post-operative day 0)

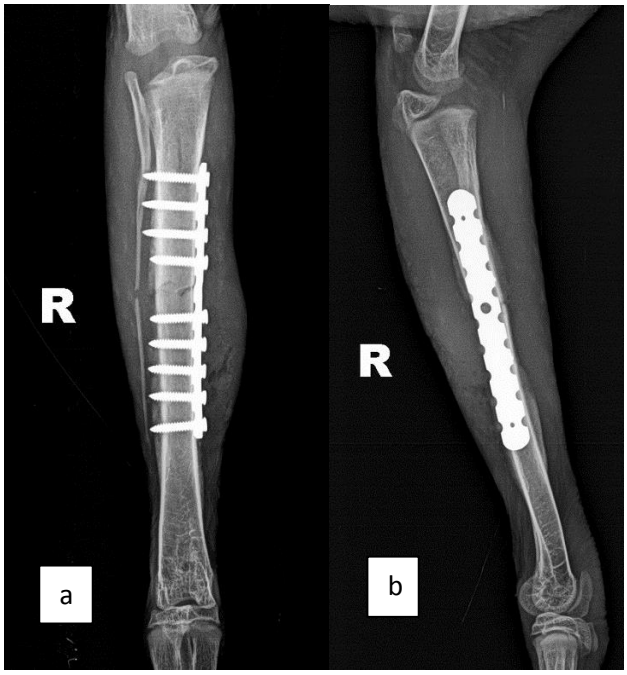


Plate 55: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing presence of fracture line in a tibiotarsus bone after repair with locking reconstruction plate in a bird of group II (7th post-operative day)

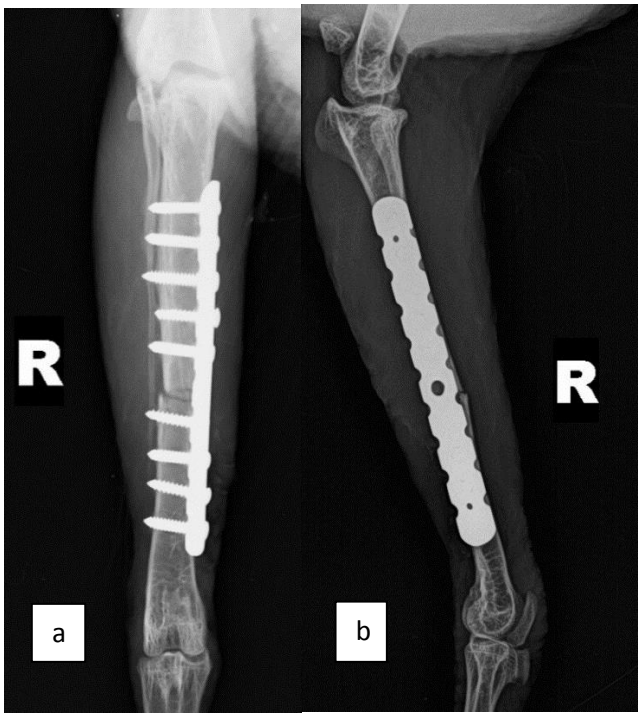


Plate 56: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing presence of fracture line in a tibiotarsus bone after repair with locking reconstruction plate in a bird of group II (7th post-operative day)

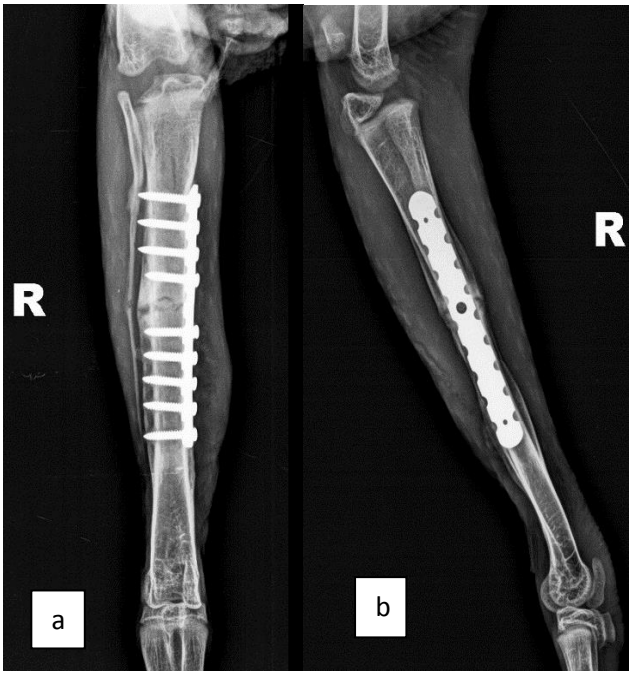


Plate 57: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing union of fractured fragments, minimal callus formation and partial visualization of fracture line in a tibiotarsus bone repaired with locking reconstruction plate in a bird of group II (14th post-operative day)

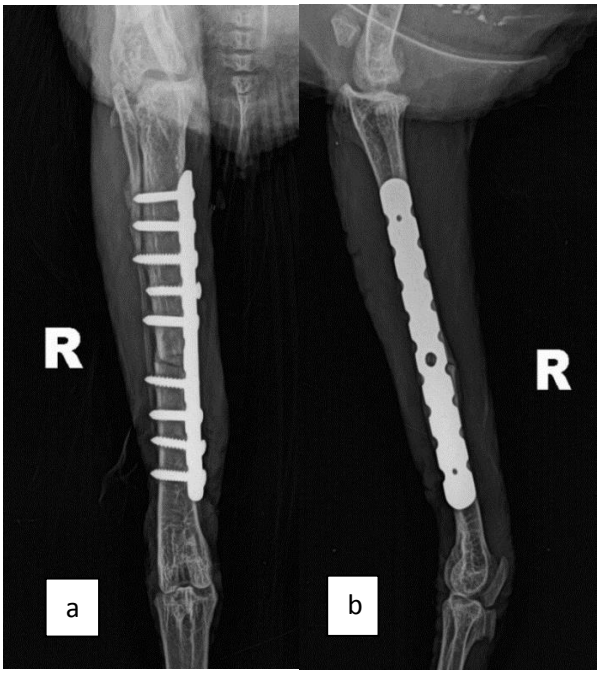


Plate 58: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing union of fractured fragments, minimal callus formation and partial visualization of fracture line in a tibiotarsus bone repaired with locking reconstruction plate in a bird of group II (14th post-operative day)

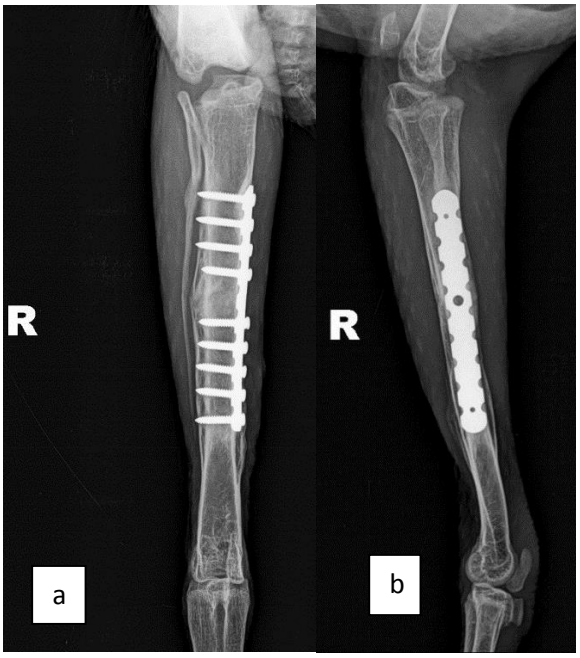


Plate 59: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation and absence of fracture line of a tibiotarsus bone repaired with locking reconstruction plate in a bird of group II (30th post-operative day)

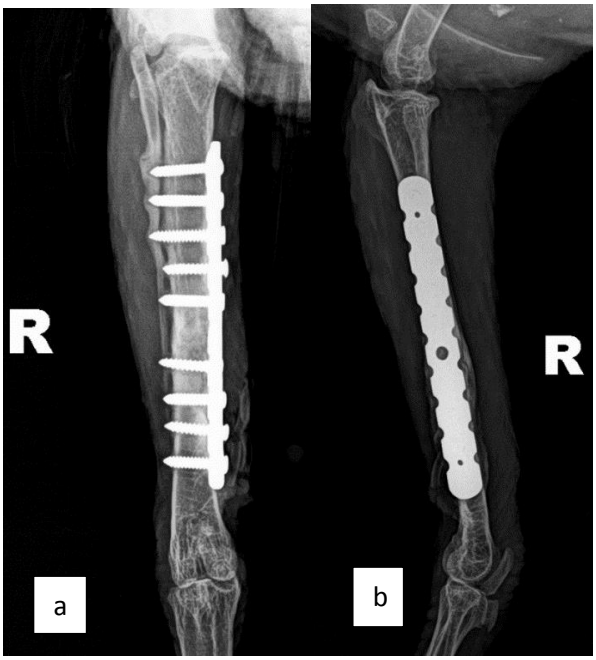


Plate 60: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation and absence of fracture line of a tibiotarsus bone repaired with locking reconstruction plate in a bird of group II (30th post-operative day)

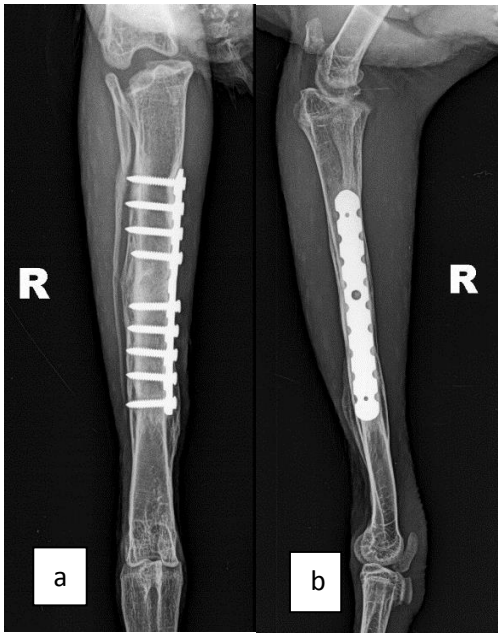


Plate 61: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodeling of fracture line of a tibiotarsus bone after repaired with locking reconstruction plate in a bird of group II (45th post-operative day)

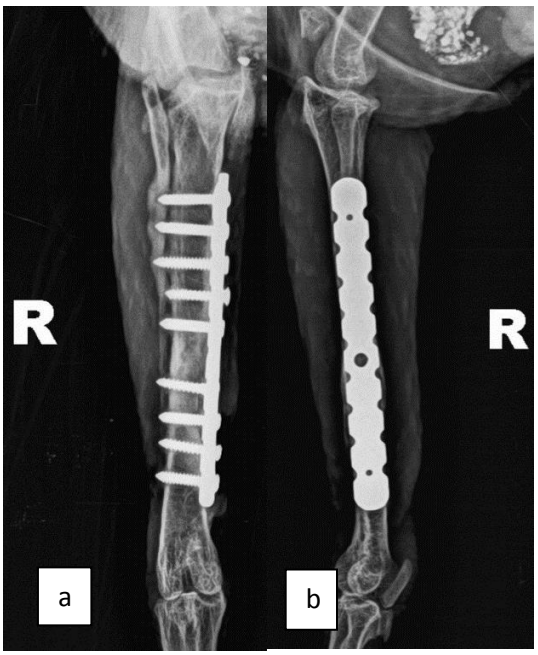


Plate 62: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodeling of fracture line of a tibiotarsus bone after repaired with locking reconstruction plate in a bird of group II (45th post-operative day)

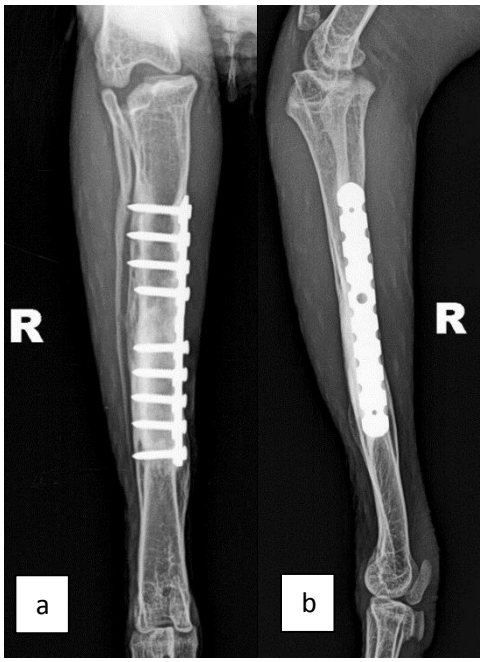


Plate 63: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing Complete union of fractured fragments, minimal callus formation, Continuation of medullary canal and remodeling of fracture line of a tibiotarsus bone after repaired with locking reconstruction plate in a bird of group II (60th post-operative day)

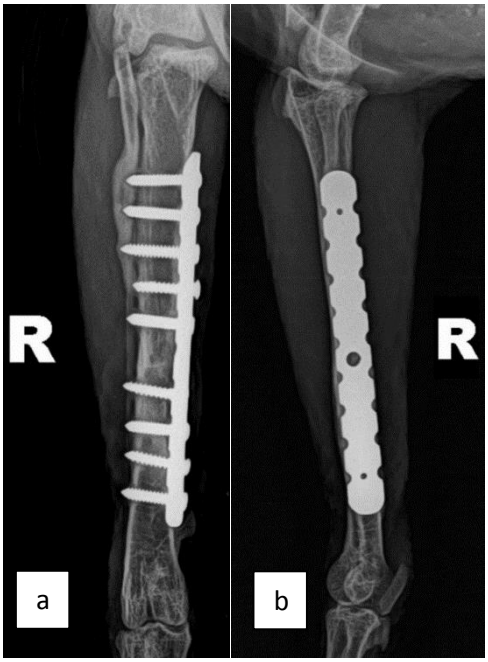


Plate 64: Cranio-caudal (a) and medio-lateral (b) views of radiograph showing complete union of fractured fragments, minimal callus formation, continuation of medullary canal and remodeling of fracture line of a tibiotarsus bone after repaired with locking reconstruction plate in a bird of group II (60th post-operative day)

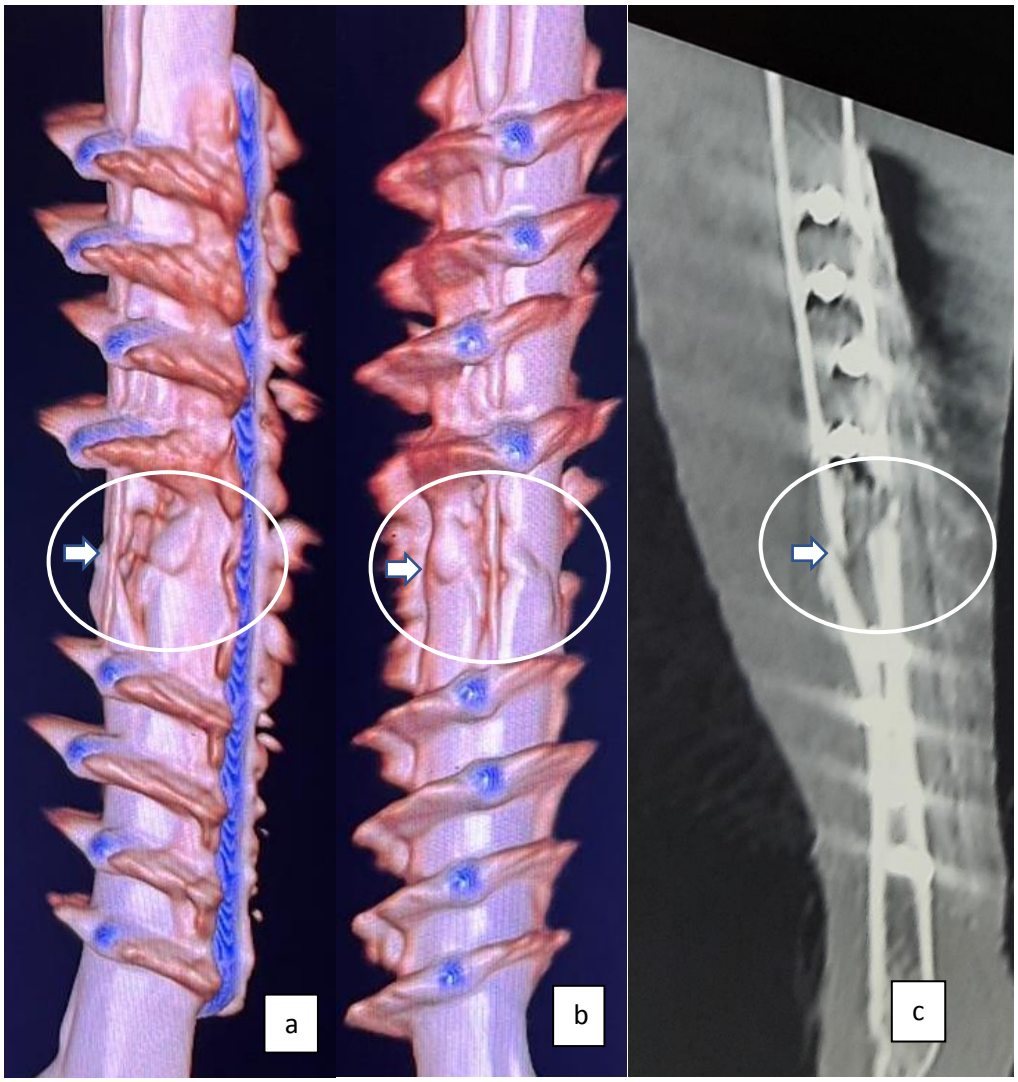


Plate 65: Cranio-caudal (a) and latero-medial (b) 3-dimensional computed Tomographic views showing presence of fracture line (arrow) and Minimal callus formation at fracture site (arrow) after repaired veterinary cuttable plate in a bird of group I (7th day). Longitudinal sagittal computed tomographic view (c) of tibiotarsus bone showing presence of fracture line (arrow) in a bird repaired with veterinary cuttable plate in a bird of group I (7th post-operative day)

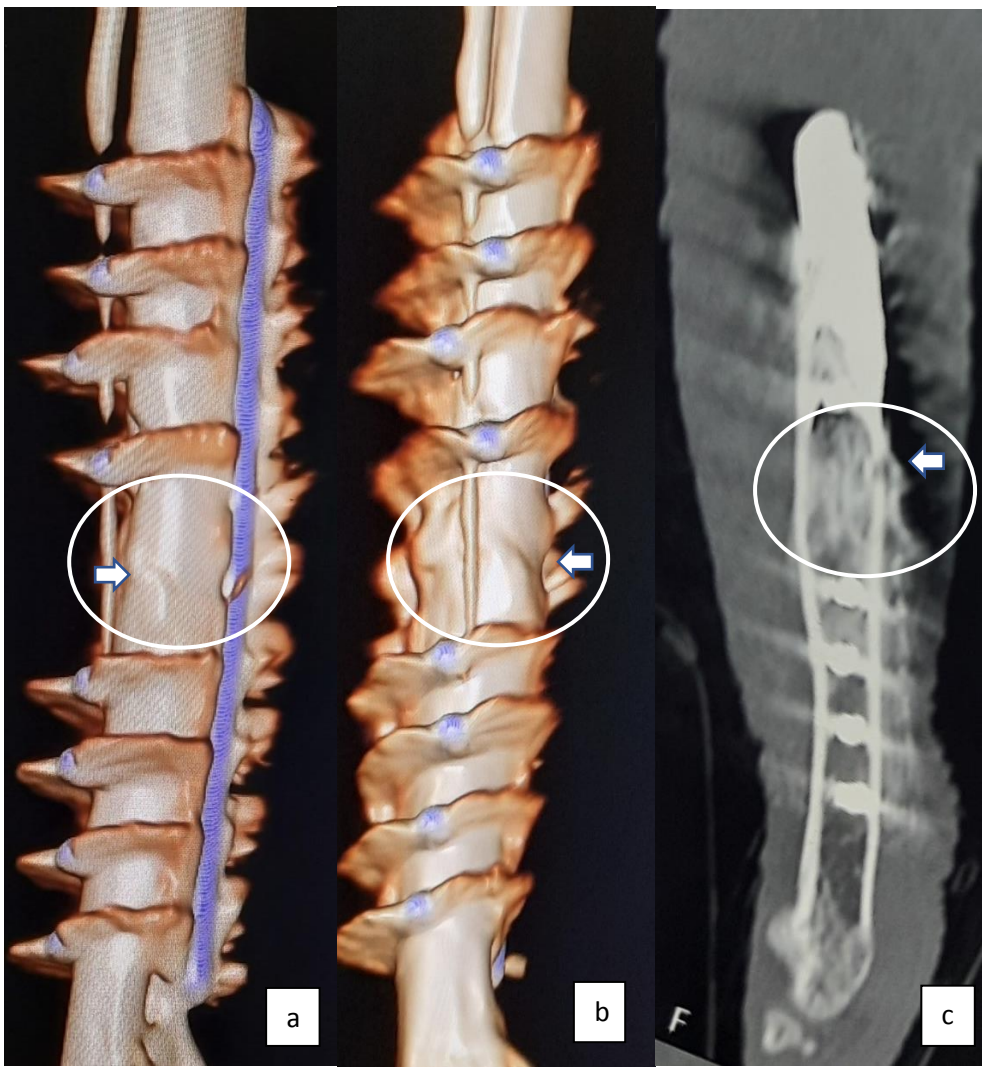


Plate 66: Cranio-caudal (a), latero-medial (b) 3-dimentional computed tomographic views and longitudinal sagittal view (c) showing union of fracture fragments (arrow) and partially visible fracture line (arrow) of tibiotarsus bone repaired with veterinary cuttable plate in a bird of group I (14th post-operative day)

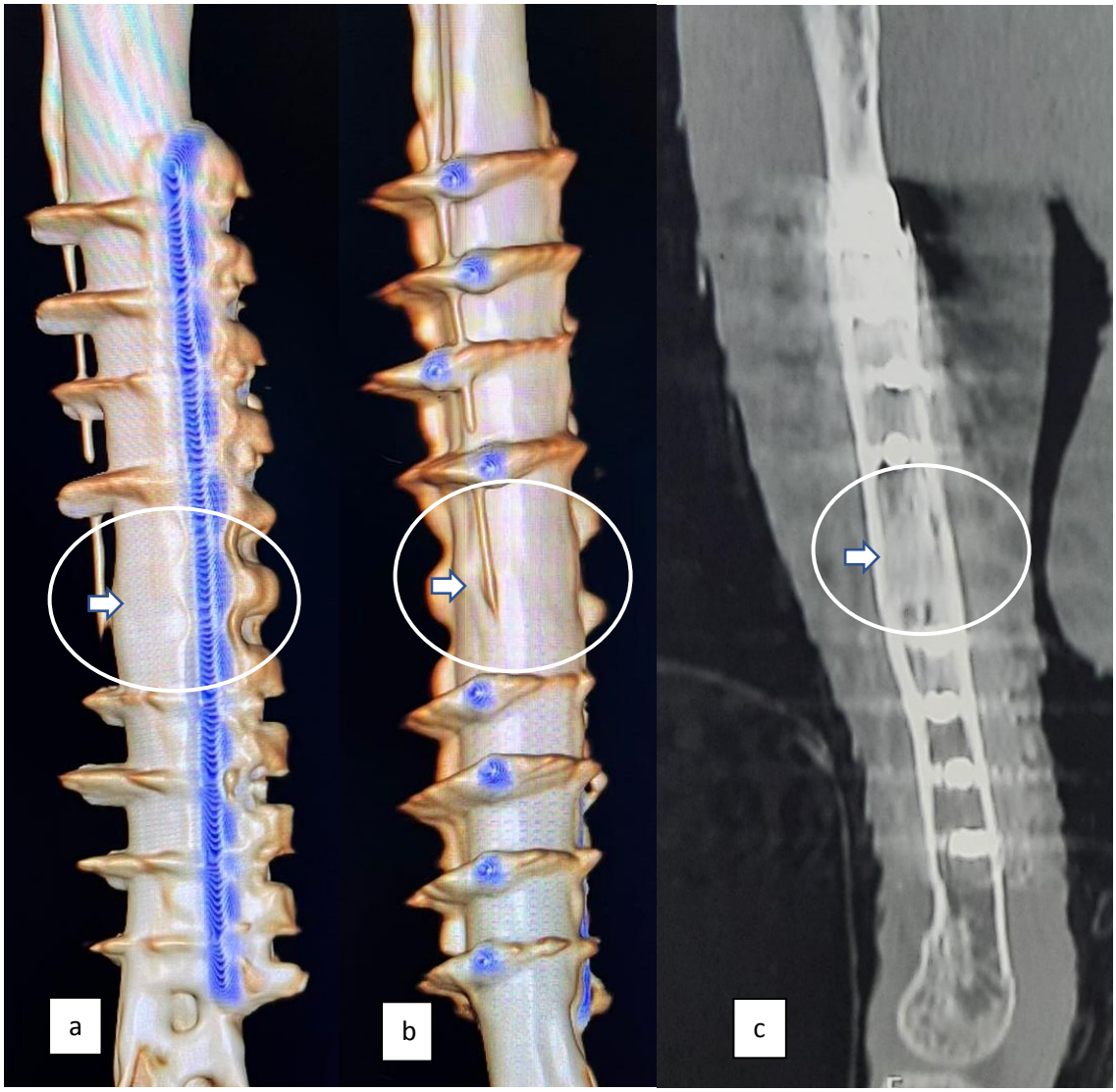


Plate 67: Cranio-caudal (a), latero-medial (b) computed tomographic 3-dimentional views and longitudinal sagittal view showing complete union of fractured fragments with remodelling of tibiotarsus bone (arrow) after repair with veterinary cuttable plate in a bird of group I (30th post-operative day)

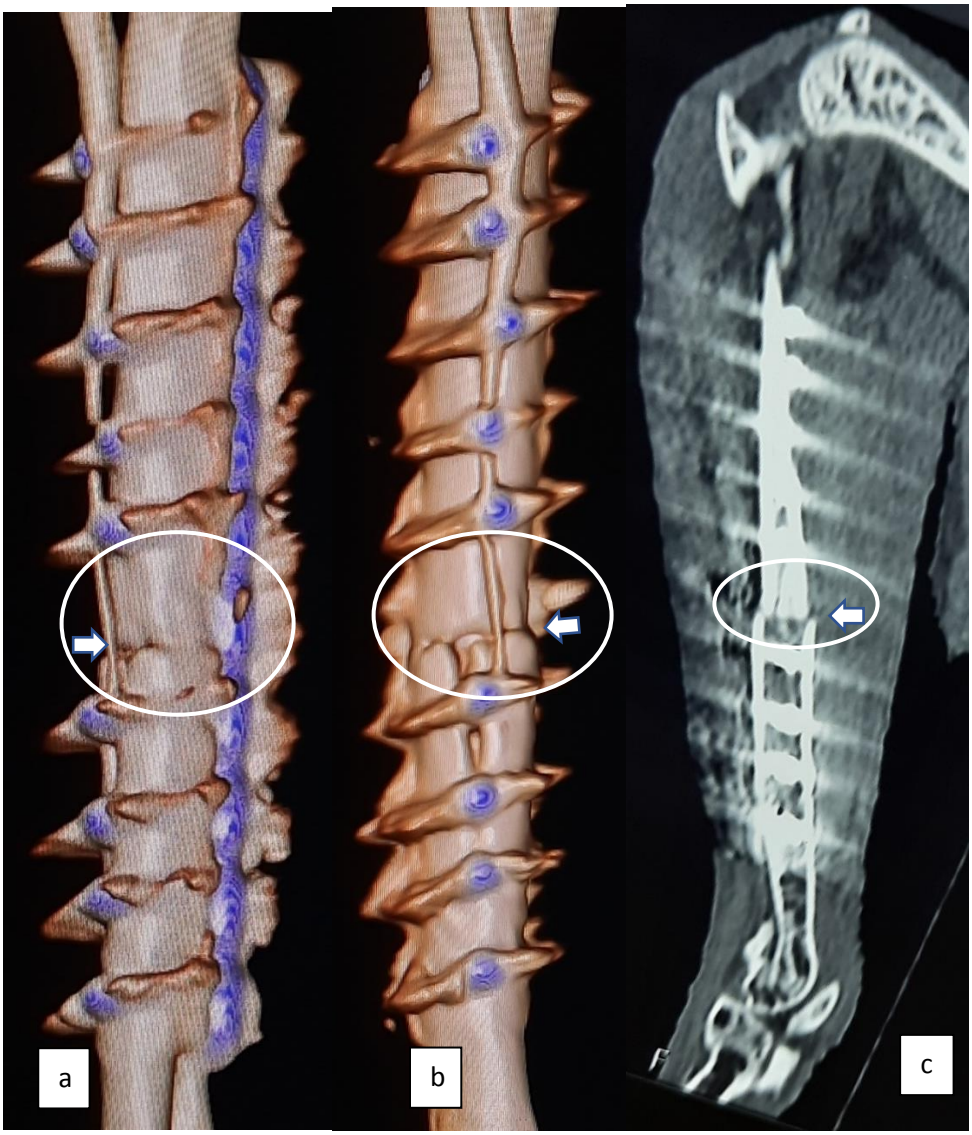


Plate 68: Cranio-caudal (a) and latero-medial (b) 3-dimensional computed tomographic views showing presence of fracture line (arrow) and minimal callus formation at fracture site (arrow) after repaired with veterinary cuttable plate in a bird of group I. Longitudinal sagittal computed tomographic view of tibiotarsus bone showing presence of fracture line (arrow) in a bird repaired with locking reconstruction plate in a bird of group I (7th post-operative day)

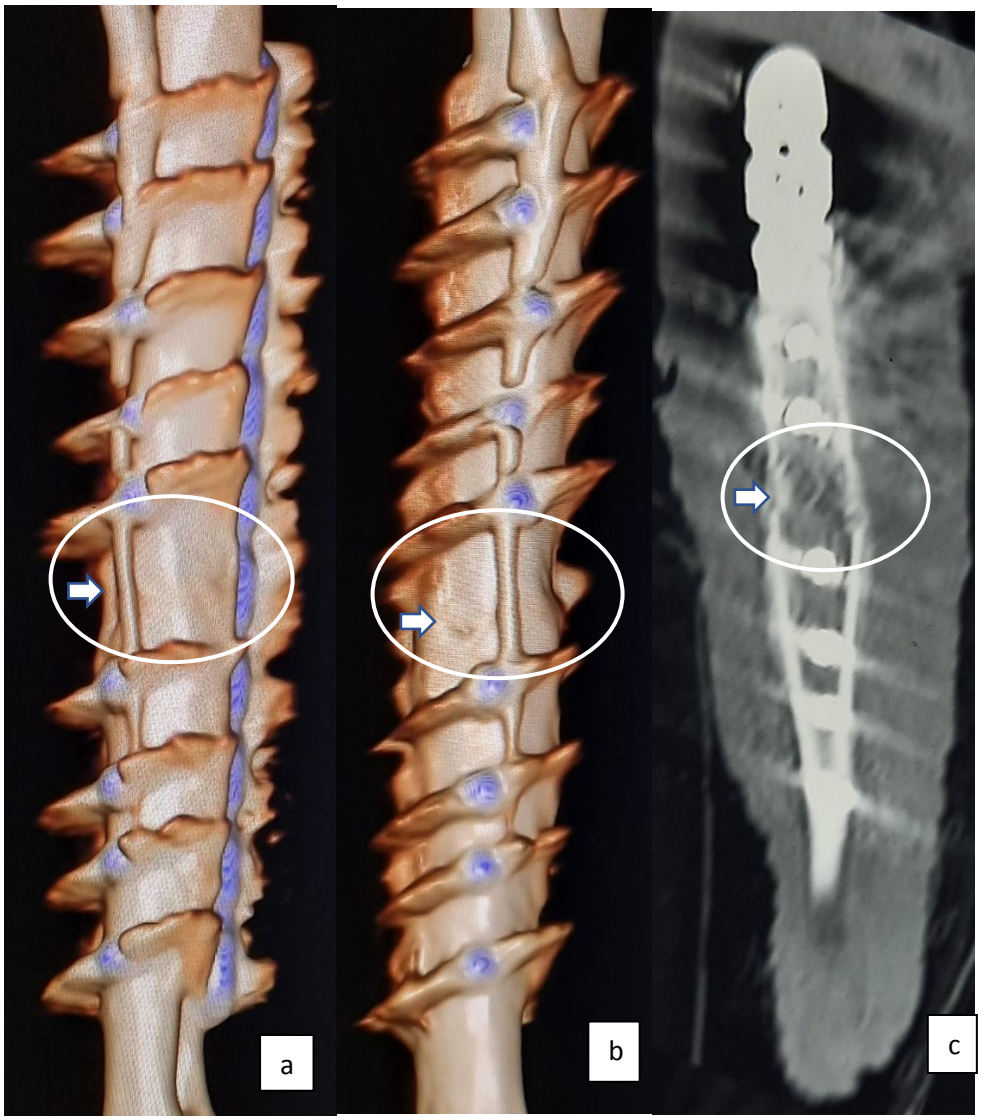


Plate 69: Cranio-caudal (a), latero-medial (b) 3-dimentional computed tomographic views and longitudinal sagittal view (c) showing union of fractured fragments (arrow) and partially visible fracture line (arrow) of tibiotarsus bone repaired with locking reconstruction plate in a bird of group II (14th post operative day)

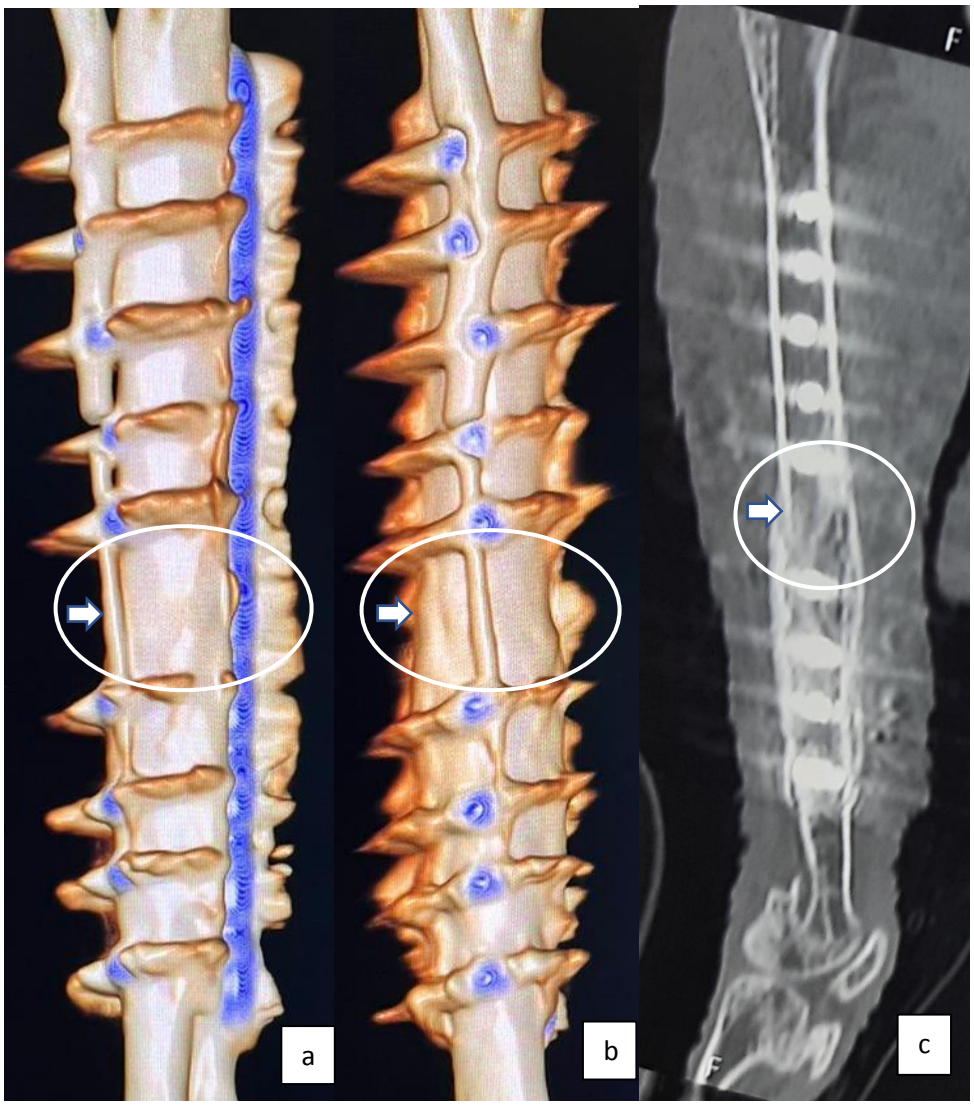


Plate 70: Cranio-caudal (a), latero-medial (b) views and longitudinal sagittal view (c) showing complete union of fractured fragments (arrow) with remodelling of tibiotarsus bone after repair with locking reconstruction plate in a bird of group II (30th post-operative day)

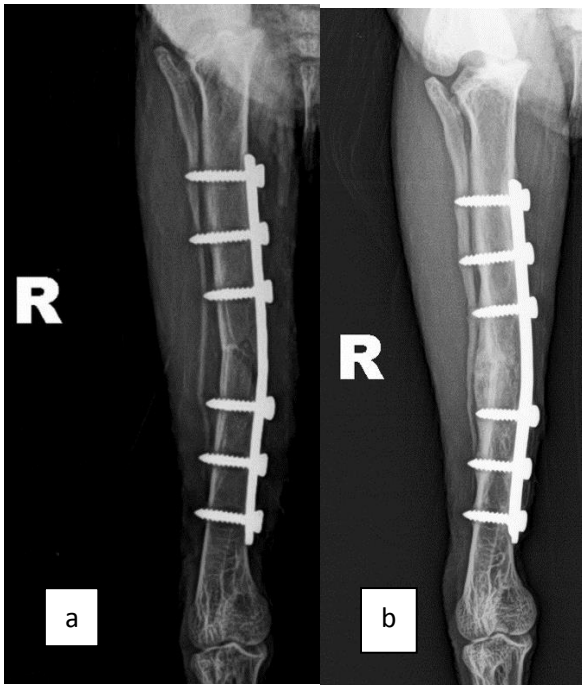


Plate 71: Cranio-caudal view of radiograph showing bending of veterinary cuttable plate in a bird of group I on 7th post-operative day (a). Union of fractured fragments on 60th post-operative day (b) in a bird of group I

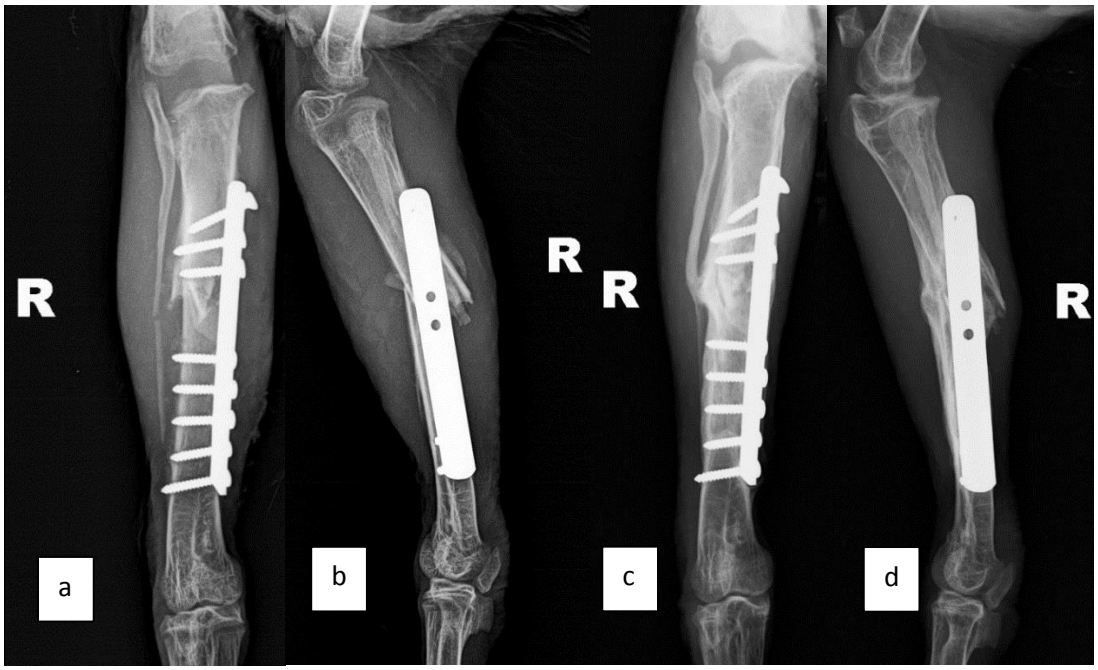


Plate 72: Cranio-caudal (a) and mediolateral (b) views of radiograph showing screw pull out form proximal fracture fragment and loss of alignment in a bird tibiotarsus fracture repaired with veterinary cuttable plate 7th post-operative day (a and b) and healing of fractured fragments in spite of screw pull out and loss of alignment on 60th post-operative day (c and d) in a bird of group I

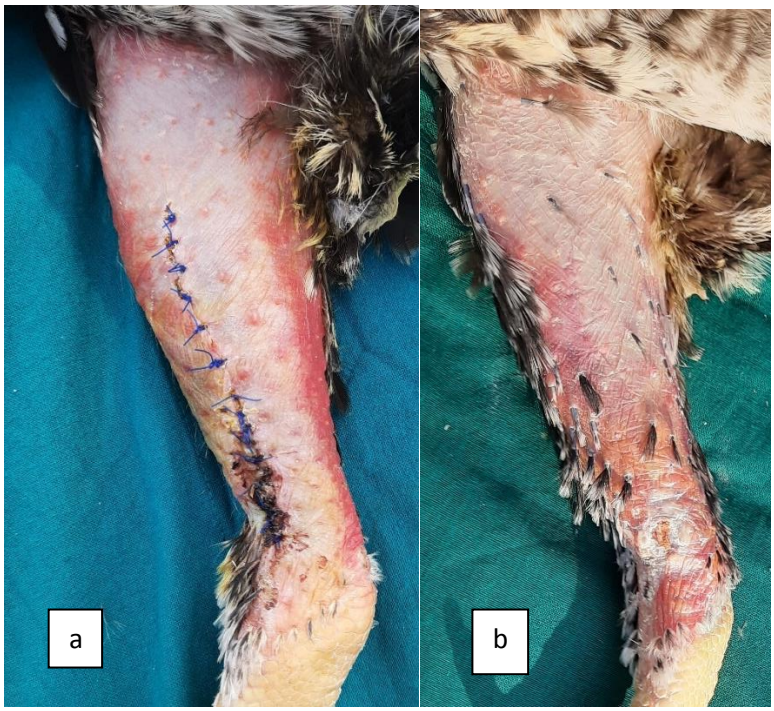


Plate 73: Photograph showing wound at distal part in medial aspect of leg on 6th post-operative day (a) and healing of skin wound on 14th post-operative day (b) in a bird of group I

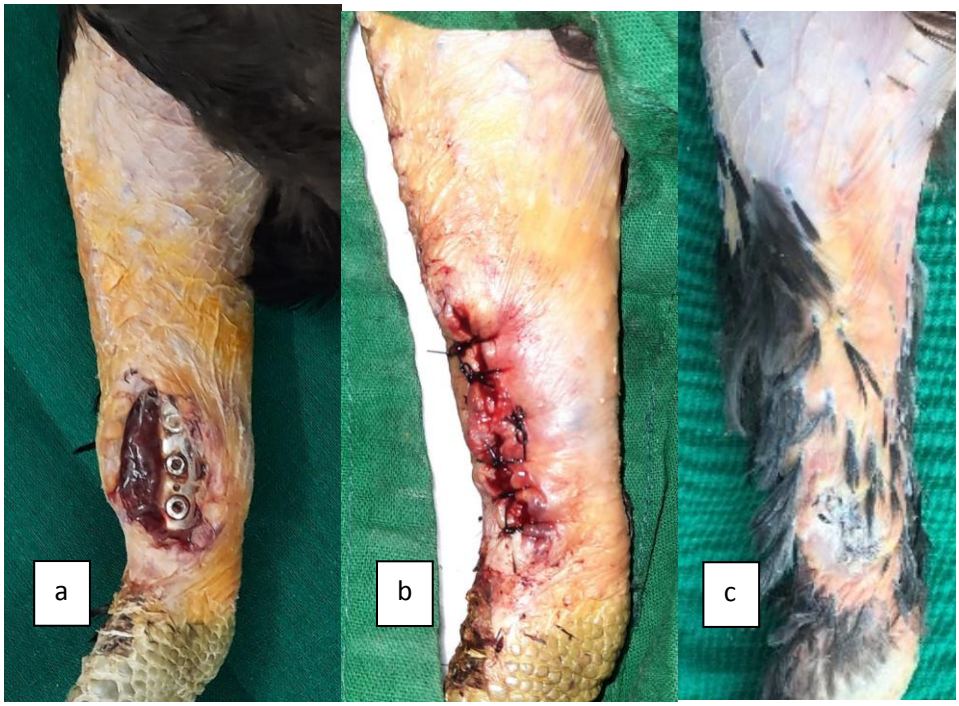


Plate 74: Photograph showing wound at medial aspect of leg on 12th post-operative Day (a) suturing on 14th day (b) and healing on 45th post-operative day by secondary intention in a bird of group II

Discussion

V. DISCUSSION

5.1 PREPARATION OF ASEEL BIRD FOR ANAESTHESIA

Each bird of both the group was fasted for 3 hours and water withheld for 1 hour before surgery. The similar fasting recommendations were given by Bennett and Kuzma (1992), Gunkel and Lafortune (2005) and Forbes (1998). With this fasting schedule they did not get any complications like vomition, aspiratory pneumonia and hypoglycaemia. The fasting might had helped to prevent the vomition, aspiratory pneumonia and minimal effect on blood glucose levels during and after the surgery in birds. Harrison (1986) opined that birds have relatively little glycogen stores in the liver. In small birds may deplete glycogen in 12-24 hours whereas in larger birds may last for 24-48 hours. So, in present study shorter duration of fasting was done for fracture repair in Aseel birds.

Pre-operative enrofloxacin antibiotic at the rate of 10 mg/kg body weight was administered intramuscular to prevent post-operative infection. Similarly, Davidson *et al.* (2005) used enrofloxacin as pre-operative antibiotic in birds to prevented infection after operation. Doneley (2006) and Verma *et al.* (2018) said that usage of meloxicam as pre-emptive analgesia in birds. Similarly same analgesic drug was used at the rate of 0.2 mg/kg body weight as pre-emptive analgesia in Aseel birds of both the group.

5.2 ANAESTHESIA

The tibiotarsus fracture repair was performed under general anaesthesia using xylazine at the rate of 5mg/kg and ketamine at the rate of 70 mg/kg were given intramuscular. All birds got anesthetised and attained surgical plane within 2 minutes after

injection without complications. Similar combination was used by Durrani *et al.* (2009) and Gunkel and Lafortune (2005) in birds for surgical intervention. They said that after anaesthesia complications like aspiratory pneumonia, hypoglycaemia and hypothermia were not observed.

General anaesthesia was adequate enough to carry out tibiotarsus fracture repair with muscle relaxation, analgesia and unconsciousness. The recovery from anaesthesia was smooth and took average time of 3 hours after induction. Similarly, induction time 1- 2 minutes, excellent analgesia and recovery took 1-2 hours after the induction with xylazine and ketamine were reported by Pallavi (2021) in backyard poultry birds. Durrani *et al.* (2009) reported xylazine at the rate of 8 mg and ketamine at the rate of 30mg cocktail treated birds showed very fast and smooth induction of anaesthesia in 1.6 minutes associated with deep analgesia, good muscle relaxation and absence of all reflexes. However, complications like hypothermia, respiratory depression and bradycardia were observed. Whereas Samour *et al.* (1984) reported inadequate analgesia and muscle relaxations were observed during surgery and sometimes violent recoveries in birds when ketamine used alone.

5.3 PREPARATION OF SURGICAL SITE

The surgical site was prepared by plucking of feathers around fracture site on medial aspect of tibiotarsus extending from stifle to hock joint. Sterile gauze bandage was wrapped from toes to hock joint which helped to prevent contamination of surgical site. Placement of bird on hot water bag in lateral recumbency prevented bird from hypothermia. Davidson *et al.* (2005) used hot water bag which prevented bird from hypothermia.

Scrubbing of surgical site with 1% chlorhexidine solution, 70% ethyl alcohol and 5% povidone iodine solutions in centrifugal direction helped to maintain asepsis at operative site similar recommendations were given by Nanjappa *et al.* (2013), Gayathri and Sunil (2018) and Kavanagh (1997). However, Bennett and Kuzma (1992) suggested that patient preparation with excessive amounts of water or alcohol could predispose the bird to hypothermia.

5.4 SURGICAL PROCEDURE

Cranio-medial approach was selected for repair of tibiotarsus fracture. An incision was made on skin extending from the stifle joint proximally to hock joint distally. Similar approach was used for bone plate fixation in tibiotarsus fracture repair in a Pomeranian goose with a locking plate by Slunsky *et al*. (2018). In the medial aspect of leg of bird fibularis longus and gastrocnemius muscles are covering the medial aspect of tibiotarsus bone. Anatomically their bellies are located in cranio-medial direction and inserting as tendons towards distal aspect of leg mentioned by Nickel *et al.* (1977). In distal part of leg slight modification in approach from cranio-medial to cranial was done to avoid damage to tibial vein which crosses caudal aspect of tibiotarsus to medial aspect in distal part as described by McLelland (1990).

On the medial aspect tension side of tibiotarsus bone, plates were fixed in both the groups of birds. The bone plate fixation on medial aspect of tibiotarsus for fracture repair was recommended by Guzman *et al*. (2007) and Slunsky *et al.* (2018) in birds.

Proper reduction and apposition were achieved by open reduction and internal fixation method. Similar method of fixation and reduction of fracture fragments were

suggested by Bennert *et al*. (2016), Slunsky *et al.* (2018) and MacCoy (1992). 2.7mm veterinary cuttable plate and 2.7mm locking reconstruction plate was used for tibiotarsus fracture repair in group I and group II birds respectively. Same size bone plate was used by Davidson *et al.* (2005) and Slunsky *et al.* (2018) for fracture repair in birds.

All the screws were placed bicortically in both the group of birds as per fixation method described by Gull *et al*. (2012). Screws placed 2 mm longer than the measured length ensured that the threads on the screw adequately engaged the trans cortex and at least 2 screws on each bone fragment were used for fixation as suggested by Langley-Hobbs *et al.* (2009).

Suture material and pattern used were satisfactory in closure of muscle and skin in both groups. Intra-operative difficulties were not observed in fixation of bone plate. Similar observations were recorded by Pallavi (2021) in back yard poultry birds.

5.5 POST-OPERATIVE CARE

The post-operative dressing of sutured wound with light weight sterile bandage gauze provided even pressure throughout the length of the operated leg and there by prevented the wound from the oedema, self-mutilation, external injury and helped in early healing by controlling wound contamination. These findings were in agreements with the findings of Burke *et al.* (2002), Hollamby *et al*. (2004), Davidson *et al*. (2005) and Gayathri and Sunil (2018).

Skin sutures were removed on 7^{th} to 14^{th} post-operative day in all the birds of both the groups. Venugopal *et al.* (2014) and Slunsky *et al.* (2018) suggested removal of sutures

after the wound healing in birds. According to Ritzman (2004) aseptic surgical wounds heal most rapidly in birds. Similarly, in both the groups wound healed faster after fracture repair.

One bird in each group had wound dehiscence on 6th post-operative day in group I and 12th post operative day in group II. However, wound healed by second intension on 14th and 45th day respectively. The cause for wound dehiscence might be due to intimate contact of skin with bone plate at distal part in medial aspect of leg and absence of muscular covering over the plate. Ritzman (2004) reported that in avian patients, wound with presence of necrotic tissue and increased tension on wound might require longer healing time. However, in these birds delayed wound healing was observed with regular antiseptic dressing.

Post-operative administration of enrofloxacin for 5 days and meloxicam for 3 days controlled post-operative infection and inflammation in birds of both the group as suggested by Davidson *et al.* (2005), Guzman *et al.* (2007), Johnston *et al.* (2008), Nanjappa *et al.* (2013), Amith and Palanivelrajan (2020) and Verma *et al.* (2018) and they could not find post-operative infection and inflammation after operation in birds.

In both the groups supportive oral calcium and multivitamin supplements helped early healing of fracture and wound in birds. This was in agreements with Hollamby *et al.* (2004) where they used oral calcium and multivitamin supplements which prevented stress and suffice the biological demand for fracture repair in birds. Physiotherapy of operated leg was done up to 14th post-operative day on alternate days which prevented muscular spasticity and joint rigidity there by all the birds in both the groups had early ambulation.

Similarly, Ferraz *et al.* (2010) and Bueno *et al.* (2015) suggested incorporation of physiotherapy in birds after fracture repair which helps early ambulation of the operated leg.

5.6 EVALUATION OF STUDY

5.6.1 Clinical evaluation

Clinical evaluation of operated birds was observed till recovery. The observations recorded were swelling, weight bearing, gait and wound healing at different intervals pre-operatively, day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups.

5.6.1.1 Swelling

In birds of the both the group had post-operative swelling of operated leg from day 0 after fracture repair. However, swelling was gradually decreased in birds of both the groups by the end of 7^{th} post-operative day. The reason for swelling was due to open reduction and internal fixation of plate and handling of soft tissue resulted in post-operative inflammatory swelling. Similar inflammatory swelling with signs of heat and redness was recorded within 36 hours of injury in birds by Carlson and Allen (1969).

5.6.1.2 Weight bearing

In both the groups birds showed improvement from pre-operative day with poor to excellent weight bearing on 60^{th}post-operative day. However, on 60^{th} post-operative day in group I, 1 bird did not show improvement in weight bearing from good to excellent where as in group II, all birds showed excellent weight bearing. The birds when compared between the group the weight bearing was better in group II birds on 30^{th} and 45^{th} interval

than group I birds and other intervals it was almost similar. The excellent weight bearing in group II might be due to locking plate provided rigid fixation and implant shared weight bearing forces on fracture fragments more effectively than non-locking veterinary cuttable plate in group I. These findings were in agreements with Pallavi (2021) where titanium locking reconstruction plates was used for fracture repair in back yard poultry. However, according to Pallavi (2021) poor weight bearing with implant failure in a bird was observed when stainless steel locking reconstruction plate used for tibiotarsus fracture in backyard poultry. Similarly, Hosmani (2019) observed early weight bearing in birds after fracture repair using locking reconstruction plates than non-locking reconstruction plates. This could be attributed to more rigid fixation in locking reconstruction plates than non-locking reconstruction plates in backyard poultry.

5.6.1.3 Lameness score

In group I and group II birds, within the group average lameness score showed improvement from pre-operative to 60^{th} post-operative day. However, when compared in between the groups the average lameness score was similar only on pre-operative and day 0. Whereas, the average lameness score in group II birds was lower on 7^{th}, 14^{th} 30^{th}, $45^{th}$and 60^{th}post-operative days of interval when compared to group I birds. This was probably due to use of locking reconstruction plate provided adequate stability and there by the lameness score improved in group II when compared to group I birds. These findings were in agreements with Pallavi (2021) where titanium and stainless-steel locking reconstruction plate used for tibiotarsus fracture repair in backyard poultry.

5.6.1.4 Wound healing

In the birds of both the groups first intension healing of wound was observed. The sutures were removed on 7th to 14th post-operative day in both the group of birds. However, each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6th and 12th post-operative days of group I and group II respectively. However, in both the groups wound healed on 14th and 45th day respectively. The close proximity of plate with skin and absence of muscle mass at distal end of operated leg could be the reason for wound dehiscence. According to Burke *et al.* (2002) 10–14 days was sufficient time for the skin to heal completely in birds.

Ritzman (2004) reported that in avian patients, wounds of the distal extremities with a reduced vascular supply and non-immobilized injuries over joints tend to heal more slowly. Conditions in the avian patient that might impede wound healing included dehydration, hypoproteinaemia, inadequate nutrition, chronic anaemia, infection, blood clots at the wound site.

Greenish discoluration of skin on medial aspect of operated leg was observed in 3 birds of group I and 2 birds of group II. The greenish discoluration might be due to tissue response to external injury. However, the greenish discolouration returned to normal gradually from day of operation to 7th post-operative day in both the group of birds. Similar observations were recorded by Degernes (1994) in birds and greenish discoloration could be due to accumulation of biliverdin pigment after the breakdown of hemoglobin and bruising of tissue 2 to 3 days post injury.

5.6.2 Radiological evaluation

5.6.2.1 Fracture line

The mean values of fracture line in group I and II birds repaired with veterinary cuttable plate and locking reconstruction plates were recorded on day 0,7th,14th,30th, 45th and 60th post-operative days.

In both the groups fracture line was visible on day 0 and 7th post-operative day. Partially visible on 14th post-operative day. Absent on 30th, 45th and 60th post-operative days.

No significant difference was observed when compared between the groups at all intervals of study with respect to fracture line.

Similar observations were recorded by Tunio *et al.* (2014) in three weeks to 12 weeks of intervals after fracture repair with external skeletal fixation in a pigeon ulna model of experimental study.

The similar findings were observed by Hosmani (2019) using locking and non-locking reconstruction plates and Pallavi (2021) with titanium and stainless-steel locking reconstruction plate for tibiotarsus fracture repair in backyard poultry.

5.6.2.2 Callus formation

The mean values of callus formation in group I and II were recorded on day 0, 7th, 14th, 30th, 45th and 60th post-operative days.

In all the birds of group I, no callus formation was observed on day 0. From 7th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds. Whereas remodelling of callus was observed on 45th and 60th post-operative days suggestive of primary healing of fracture fragments in birds.

In group I birds, 1bird showed slight bending of plate on 7th post-operative day. Similar bending of plate was observed by Doijode (2018) with veterinary cuttable plate fixation in goats for long bone fracture repair and Ramesh *et al*. (2018) observed plate bending on 15th post-operative day at the fracture site in a puppy with veterinary cuttable plate for femur fracture repair. This was probably due to two unpurchased holes near fracture site, elasticity of veterinary cuttable plate and hyper activities of bird. In another 2 birds of group I showed mal-alignment of fractured fragment on 7th post-operative day due to first proximal screw pull out and fixation of only two screws in upper fragment where as in another bird a small piece of bone fragment came out from fracture alignment. However, in all these birds fracture healed completely by the end of study interval. The similar observations were recorded by Hamilton *et al.* (2009) where ileal fracture repaired in cats with veterinary cuttable plate of size 2.7mm resulted in loss of alignment and screw loosening.

In all the birds of group II, no callus formation was observed on day 0 and 7th post-operative day. However, from 14th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds. Whereas remodelling of callus was observed on 45th and 60th post-operative days suggestive of primary healing of fracture fragments in birds.

In group II birds, mal-alignment of fracture fragments, bending of plate and pull out of screws were not observed due to use of locking reconstruction plate.

When compared in between the groups the earlier callus formation on 7th day was observed in group I than group II. However, no significant difference was observed at remaining intervals of the study in both the groups of birds. The reason might be due to use of non-locking veterinary cuttable plate and its elastic nature (Cabassu, 2001).

Bennett and Kuzma (1992) reported that primary bone healing in mammals occurs under conditions of rigid fixation and bony union occurs through direct growth of haversian systems across the fracture with minimal or no external callus formation.

Bennett and Kuzma (1992) reported that radiolucent medullary canal of the pneumatic humerus became denser in radiograph over time, initially because of haemorrhage then later appearance of connective tissue and endosteal callus formation. On 9 weeks post fracture repair in birds, both endosteal and periosteal callus were evident in radiographs. Callus consisted of cancellous bone, cartilage and fibrous connective tissue.

Williams *et al.* (1987) reported that radiographic evidence of callus formation was observed at 3 weeks after implant placement in pigeons. Hollamby (2004) reported that tibiotarsus fracture stabilized with interlocking nail in bald eagle showed clinical union on 4 weeks post-operation. These findings were in agreements with present study.

5.6.2.3 Bone union

The mean values of bone union recorded in group I with veterinary cuttable plate and group II with locking reconstruction plate on day 0, 7th, 14th, 30th, 45th and 60th post-operative days.

In group I birds on day 0 bone union was not observed. However, from 7th post-operative day to 60th post-operative day progressive healing of fracture with minimum callus formation was observed. This suggested primary union of fracture fragments with remodelling of callus and continuation of medullary canal. In 2 birds of group I, showed mal-alignment of fracture fragments with callus formation on 7th post operative day however, in these birds union of fracture was observed by the end of interval of study.

In group II birds, on day 0 and 7th post-operative day bone union was not observed. However, from 14th post-operative day to 60th post-operative day progressive healing of fracture with minimum callus formation and union of fracture fragments were observed. This showed remodelling of callus and continuation of medullary canal suggestive of primary healing. Bush *et al*. (1976) and Williams *et al.* (1987) reported that clinically well-aligned stable fracture healed faster within 3 weeks in birds which was faster than mammalian bone union.

Between the groups with respect to bone union no significant difference was observed. When compared in between the groups the earlier callus formation on 7th day was observed in group I than group II. However, no significant difference was observed at remaining intervals of the study in both the groups of birds. The reason might be due to use of non-locking veterinary cuttable plate and its elastic nature (Cabassu, 2001).

Kuzma and Hunter (1991) reported minimal callus was produced in six of eight fractures repaired with bone plates indicating primary bone healing in birds which was in agreement with present study findings.

Bennett and kuzma (1992), Hosmani (2019) and Pallavi (2021) reported complete osseous union of fracture fragments on radiographs at 6th week post operation in birds which was in agreement with present study findings.

5.6.3 Computed tomographic evaluation

In both the groups computed tomographic evaluation of fracture healing was done on 7th, 14th and 30th post-operative days.

Three-dimensional view of cranio-caudal, latero-medial and longitudinal sagittal section of repaired tibiotarsus bone with plating was evaluated in respective intervals in both the groups.

In both the groups 3-dimentional view showed presence of fracture line on 7th post-operative day, partially visible on 14th post-operative day and complete absence on 30th post-operative day suggestive of primary healing with complete union of fracture. The fracture healing was also supported by longitudinal sagittal view with similar trend of fracture healing.

There was no difference in fracture healing when compared between the groups.

The computed tomography at different interval supported the radiographic finding at corresponding intervals and it helped in viewing the fracture healing in all the dimensions of bone and in-situ position of implant with bone fragments until fracture union in birds. These findings were in agreement with Braunstein *et al.* (1986). Berry and Thrall (2007) and Nicholson *et al.* (2019).

Berry and Thrall (2007) reported that radiographs usually provide good images for evaluation of fracture healing however the interpretation often hampered by the superimposition of the tissue. So computed tomography images aids in better visualisation of fracture healing than radiograph.

Nicholson *et al.* (2021) opined that computed tomographic scanning can evaluate bridging callus in the late stages of healing to confirm union.

The similar pattern of mid-diaphyseal femur fracture healing evaluated by Braunstein *et al.* (1986) and compared computed tomography with plain radiography in adult female sheep. By 3 weeks, callus was visible, however at 6 weeks, a trabecular pattern in the callus was seen on plain films however not on computed tomography. There was progressive organization of the callus on both studies. At 24 weeks, computed tomography demonstrated fracture lines not seen due to overlying callus on plain films and also more accurately showed incomplete union. By 36 weeks, healing was essentially complete according to both modalities, although there still were small gaps in the callus detectable on computed tomography but not on plain films.

5.7 COMPLICATIONS

In both the group of bird's complications were recorded during the study period.

In group I, 2 birds had implant related post-operative complications. In 1 bird slight bending of plate was observed at diaphyseal region of fracture. Similar findings observed by Gull *et al*. (2012) that plate bending was observed on 14^{th} post-operative days in repair of ulnar fracture with 1 mm mini plate in pigeons. However, in present study implant was

stable enough to bear the weight of the operated leg. On 60th post-operative day complete healing of fracture was observed along with bending of plate. In another bird proximal screw pull out was observed on 7th post-operative day and it maintained till healing of the bone. Ramesh *et al.* (2018) reported that on 15th post operative day plate bending was observed and on 30th post-operative day screw loosening was observed in puppies treated for femur fracture using 2.7mm veterinary cuttable plate.

Similar observations were observed by Gull *et al.* (2012) screw loosening observed in ulnar fracture stabilized with 1.3-mm adaption plate in pigeons on post-operative day. Hamilton *et al.* (2009) reported that screw loosening in cats treated for ileal fracture with veterinary cuttable plate of size 2.7mm.

In group II birds no implant related complications were observed.

Each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6th and 12th post-operative days of group I and group II respectively due to close proximity of plate with skin and absence of muscle mass at distal end of operated leg. However, these wounds healed on 14th and 45th post-operative days.

In agreements with present study findings Kuzma (1990) and Ritzman (2004) reported distal extremities of bird had little soft tissue for support covered by tendons and skin. Wounds of the distal extremities with a reduced vascular supply and non-immobilized injuries over joints tend to heal more slowly.

Summary

VI. SUMMARY

The experimental research on comparative evaluation of veterinary cuttable plate and locking reconstruction plate for tibiotarsus fracture repair in Aseel bird was carried out at Department of Veterinary Surgery and Radiology, Veterinary College, Bidar. The permission for conducting the experimental research was obtained by institutional animal ethical committee vide reference no. IAEC (No.17/2021/VCB/VSR).

Each bird of both the group was fasted for 3 hours and water withheld for 1 hour before surgery. With this fasting schedule they did not get any complications like vomition, aspiratory pneumonia and hypoglycaemia. The fasting might had helped to prevent the vomition, aspiratory pneumonia and minimal effect on blood glucose levels during and after the surgery in birds. So, in the present study shorter duration of fasting was done for fracture repair in Aseel birds.

Pre-operative enrofloxacin antibiotic at the rate of 10 mg/kg body weight was administered intramuscular which prevented post-operative infection. Meloxicam was used as pre-emptive analgesia at the rate of 0.2 mg/kg body weight in Aseel birds of both the groups which provided analgesia intra-operatively and post-operatively.

The tibiotarsus fracture repair was performed under general anaesthesia using xylazine at the rate of 5mg/kg and ketamine at the rate of 70 mg/kg were given intramuscular. All birds got anesthetised and attained surgical plane within 2 minutes after injection. Tibiotarsus fracture in each bird was induced manually. In all the birds simple oblique, transverse, communiated and oblique communiated fracture of tibiotarsus were

observed. Induction of fracture was confirmed by mal-alignment of fractured fragments and radiographic imaging.

General anaesthesia was adequate enough to carry out tibiotarsus fracture repair with muscle relaxation, analgesia and unconsciousness. All birds got anesthetised and attained surgical plane at average of 120 seconds. The recovery from anaesthesia was smooth and took average time of 3 hours after induction.

The surgical site was prepared by plucking of feathers around fracture site on medial aspect of tibiotarsus extending from stifle to hock joint. Sterile gauze bandage was wrapped from toes to hock joint which helped to prevent contamination of surgical site. Placement of bird on hot water bag in lateral recumbency prevented bird from hypothermia. Scrubbing of surgical site with 1% chlorhexidine solution, 70% ethyl alcohol and 5% povidone iodine solutions in centrifugal direction helped to maintain asepsis at operative site.

Cranio-medial approach was selected for repair of tibiotarsus fracture. An incision was made on skin extending from the stifle joint proximally to hock joint distally. In the medial aspect of leg of bird fibularis longus and gastrocnemius muscles are covering the medial aspect of tibiotarsus bone. Anatomically their bellies are located in cranio-medial direction and inserting as tendons towards distal aspect of leg. In distal part of leg slight modification in approach from cranio-medial to cranial was done to avoid damage to tibial vein which crosses caudal aspect of tibiotarsus to medial aspect in distal part. On the medial aspect tension side of tibiotarsus bone, plates were fixed in both the groups of birds.

Proper reduction and apposition were achieved by open reduction and internal fixation method. 2.7mm veterinary cuttable plate and 2.7mm locking reconstruction plate was used for tibiotarsus fracture repair in group I and group II birds respectively. Muscular fascia sutured with 2-0 monofilament poliglecaprone 25 in lockstitch pattern was satisfactory to closure of muscle bundles in both the groups and 2-0 monofilament polypropylene was satisfactory to closure of skin with simple interrupted pattern in group I. 2-0 monofilament polyamide was satisfactory to closure of skin in simple interrupted pattern in group II.

The post-operative dressing of sutured wound with light weight sterile bandage gauze provided even pressure throughout the length of the operated leg and there by prevented the wound from the oedema, self-mutilation, external injury and helped in early healing by controlling wound contamination. Skin sutures were removed on 7^{th} to 14^{th} post-operative day in all the birds of both the groups.

One bird in each group had wound dehiscence on 6^{th} post-operative day in group I and 12^{th} post operative day in group II. However, wound healed on 14^{th} and 45^{th} post-operative day by second intension. The cause for wound dehiscence might be due to intimate contact of skin with bone plate at distal part in medial aspect of leg and absence of muscular covering over the plate.

Post-operative administration of enrofloxacin for 5 days and meloxicam for 3 days controlled post-operative infection and inflammation in birds of both the groups. In both the groups supportive oral calcium and multivitamin supplements helped early healing of fracture and wound in birds. Physiotherapy of operated leg was done up to 14^{th} post-

operative day on alternate days which prevented muscular spasticity and joint rigidity there by all the birds in both the groups had early ambulation.

Clinical evaluation of operated birds was observed till recovery. The observations recorded were swelling, weight bearing, gait and wound healing at different intervals pre-operatively, day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days in both groups.

In birds of the both the group had post-operative swelling of operated leg from day 0 after fracture repair. However, swelling was gradually decreased in birds of both the groups by the end of 7^{th} post-operative day. The reason for swelling was due to open reduction and internal fixation of plate and handling of soft tissue resulted in post-operative inflammatory swelling.

In both the groups birds showed improvement from pre-operative day with poor to excellent weight bearing on 60^{th} post-operative day. However, on 60^{th} post-operative day in group I, 1 bird did not show improvement in weight bearing from good to excellent where as in group II, all birds showed excellent weight bearing. The birds when compared between the group the weight bearing was better in group II birds on 30^{th} and 45^{th} interval than group I birds and at other intervals it was almost similar. The excellent weight bearing in group II might be due to locking plate provided rigid fixation and implant shared weight bearing forces on fracture fragments more effectively than non-locking veterinary cuttable plate in group I.

In group I and group II birds, within the group average lameness score showed improvement from pre-operative to 60^{th} post-operative day. However, when compared in

between the groups the average lameness score was similar only on pre-operative and day 0. Whereas, the average lameness score in group II birds was better on 7^{th}, 14^{th}, 30^{th}, $45^{th}$and 60^{th} post-operative days of interval when compared to group I birds. This was probably due to use of locking reconstruction plate provided adequate stability and there by the lameness score improved in group II when compared to group I birds.

In the birds of both the groups first intension healing of wound was observed. The sutures were removed on 7^{th} to 14^{th} post-operative day in both the group of birds. However, each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6^{th} and 12^{th} post-operative days of group I and group II respectively. However, these wounds healed on 14^{th} and 45^{th} post-operative days in group I and group II respectively. The close proximity of plate with skin and absence of muscle mass at distal end of operated leg could be the reason for wound dehiscence.

Greenish discolouration of skin on medial aspect of operated leg was observed in 3 birds of group I and 2 birds of group II. The greenish discoloration might be due to tissue response to external injury. However, the greenish discolouration returned to normal gradually from day of operation to 7^{th} post-operative day in both the group of birds.

The mean values of fracture line in group I and II birds repaired with veterinary cuttable plate and locking reconstruction plates were recorded on day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days. In both the groups fracture line was visible on day 0 and 7^{th} post-operative day. Partially visible on 14^{th} post-operative day and absent on 30^{th}, 45^{th} and 60^{th} post-operative days. No significant difference was observed when compared between the groups at all intervals of study with respect to fracture line.

The mean values of callus formation in group I and II were recorded on day 0, 7th, 14th, 30th, 45th and 60th post-operative days. In all the birds of group I, no callus formation was observed on day 0. From 7th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds. Whereas remodelling of callus was observed on 45th and 60th post-operative days suggestive of primary healing of fracture fragments in birds.

In group I birds, 1bird showed slight bending of plate on 7th post-operative day. This was probably due to two un purchased holes near fracture site, elasticity of veterinary cuttable plate and faulty management. In another 2 birds of group I showed mal-alignment of fractured fragment on 7th post-operative day due to first proximal screw pull out and where as in another bird fixation of only two screws in upper fragment and a small piece of bone fragment came out from fracture alignment. However, in all these birds fracture healed completely by the end of study interval.

In all the birds of group II, no callus formation was observed on day 0 and 7th post-operative day. However, from 14th post-operative day to 30th post-operative day minimal callus formation was observed at fracture site in all the birds. Whereas remodelling of callus was observed on 45th and 60th post-operative days suggestive of primary healing of fracture fragments in birds. In group II birds, mal-alignment of fracture fragments, bending of plate and pull out of screws were not observed due to use of locking reconstruction plate.

When compared in between the groups the earlier callus formation on 7th day was observed in group I than group II. However, no significant difference was observed at

remaining intervals of the study in both the groups of birds. The reason might be due to use of non-locking veterinary cuttable plate and its elastic nature.

The mean values of bone union recorded in group I with veterinary cuttable plate and group II with locking reconstruction plate on day 0, 7^{th}, 14^{th}, 30^{th}, 45^{th} and 60^{th} post-operative days. In group I birds on day 0 bone union was not observed. However, from 7^{th} post-operative day to 60^{th} post-operative day progressive healing of fracture with minimum callus formation was observed. This suggested primary union of fracture fragments with remodelling of callus and continuation of medullary canal. In 2 birds of group I, showed mal-alignment of fracture fragments with callus formation on 7^{th} post operative day however, in these birds union of fracture was observed by the end of interval of study. In group II birds, on day 0 and 7^{th} post-operative day bone union was not observed. However, from 14^{th} post-operative day to 60^{th} post-operative day progressive healing of fracture with minimum callus formation and union of fracture fragments were observed. This showed remodelling of callus and continuation of medullary canal suggestive of primary healing.

Between the groups with respect to bone union no significant difference was observed. When compared in between the groups the earlier callus formation on 7^{th} day was observed in group I than group II. However, no significant difference was observed at remaining intervals of the study in both the groups of birds.

In both the groups computed tomographic evaluation of fracture healing was done on 7^{th}, 14^{th} and 30^{th} post-operative days. Three-dimensional view of cranio-caudal, medio-lateral and longitudinal sagittal section of repaired tibiotarsus bone with plating was evaluated in respective intervals in both the groups. In both the groups 3-dimentional view

showed presence of fracture line on 7th post-operative day, partially visible on 14th post-operative day and complete absence on 30th post-operative day suggestive of primary healing with complete union of fracture. The fracture healing was also supported by longitudinal sagittal view with similar trend of fracture healing. There was no difference in fracture healing when compared between the groups.

The computed tomography at different interval supported the radiographic finding at corresponding intervals and it helped in viewing the fracture healing in all the dimensions of bone and in-situ position of implant with bone fragments until fracture union in birds.

In both the group of birds complications were recorded during the study period. In group I, 2 birds had implant related post-operative complications. In 1 bird slight bending of plate was observed at diaphyseal region of fracture. However, in this bird implant was stable enough to bear the weight of the operated leg. On 60th post-operative day complete healing of fracture was observed along with bending of plate. In another bird proximal screw pull out was observed on 7th post-operative day and it maintained till healing of the bone. In group II birds no implant related complications were observed. Each bird in both the groups had wound dehiscence at distal part in the medial aspect of operated leg on 6th and 12th post-operative days respectively due to close proximity of plate with skin and absence of muscle mass at distal end of operated leg. However, these wounds healed on 14th and 45th post-operative days.

Based on above findings following conclusions were derived.

1. Veterinary cuttable plate and locking reconstruction plate provided stable fixation for fracture repair of tibiotarsus bone in Aseel bird however the locking reconstruction plate has cutting edge over the veterinary cuttable plate.

2. Weight bearing and lameness score showed better in group II birds compared to group I at post-operative intervals.

3. Radiological findings showed primary healing of fracture with minimal callus formation at fracture site by bone plating in both groups.

4. Computed tomographic evaluation of fracture in both groups showed similar healing pattern as radiograph at corresponding intervals and supported the radiographic findings in all dimension of bone.

5. In both the groups clinical and radiological union of fracture was earlier by 45^{th} post-operative day in Aseel birds.

6. Implant related complications like plate bending and screw pull-out were observed only in group I birds.

7. In both groups wound dehiscence was observed at distal end of operated leg.

8. Anaesthetic protocol was satisfactory to conduct of fracture repair in Aseel birds.

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Abstract

VIII. ABSTRACT

COMPARATIVE EVALUATION OF VETERINARY CUTTABLE PLATE AND LOCKING RECONSTRUCTION PLATE FOR TIBIOTARSUS FRACTURE REPAIR IN ASEEL BIRD

Student	March	Major advisor
Gurudev Karajagi	2022	Dr. Bhagavantappa B

Experimental study was conducted in 12 Aseel birds of either sex. The permission for conducting the experimental research was obtained by institutional animal ethical committee vide reference no. IAEC (No.17/2021/VCB/VSR). The tibiotarsus bone fractures were induced under general anaesthesia by using xylazine and ketamine. Aseel birds fracture repaired using 2.7 mm veterinary cuttable plate in group I and 2.7mm locking reconstruction plate in group II. Xylazine at the rate of 5mg/kg body weight and ketamine at the rate of 70mg/kg per kg body weight was provided satisfactory muscle relaxation, analgesia and unconsciousness for conduct of fracture repair in both the groups. Veterinary cuttable plate and locking reconstruction plate provided stable fixation for fracture repair of tibiotarsus bone in Aseel bird. However, the locking reconstruction plate has cutting edge over the veterinary cuttable plate. Weight bearing and lameness score showed better in group II birds compared to group I at post-operative intervals. Radiological findings showed primary healing of fracture with minimal callus formation at fracture site by bone plating in both groups. Computed tomographic evaluation of fracture in both groups showed similar healing pattern as radiograph at corresponding intervals and supported the radiographic findings in all dimension of bone. In both the groups clinical and radiological union of fracture was earlier by 45^{th} post-operative day in Aseel birds. Implant related complications like plate bending and screw pull-out were observed only in group I birds. In both groups wound dehiscence was observed at distal end of operated leg. Anaesthetic protocol was satisfactory to conduct of fracture repair in Aseel birds. So concluded that if proper body size of bird is there, then with suitable selection of implants and its accurate application technique in long bone fracture can be easily managed with internal fixation without much complications.