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Clinical evaluation of minimally invasive plate osteosynthesis in tibial and metatarsal fracture repair in goats

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Abstract
In this study Minimally Invasive Plate Osteosynthesis (MIPO) technique using Locking Compression Plates (LCP) was employed in the stabilization of 2 tibial and 4 metatarsal fractures in goats. Immediate postoperative radiographs revealed good alignment and apposition of the fracture fragments in all the goats. All the goats showed partial weight bearing from the 1st post-operative day. Full weight bearing was observed between 7th to 30th post-operative days with a mean of 13.6 ±4.11 days. Postoperative radiographs on 60thday revealed complete radiological union in five out of six goats. The MIPO techniue using LCPs in tibial and metatarsal fracture repair, showed remarkable improvement with normal limb function and maintaining good implant stability throughout the treatment period without any complications.

Keywords: minimally invasive plate osteosynthesis, long bone fractures, in small ruminants.

Introduction
Fractures in goat are most common orthopedic (Singh and Nigam, 1981) and non-infectious causes of lameness (Mathews, 1999) [18]. Goats are very much prone to fractures. Because of their dense population in urban areas, which predisposes them to accidents and dog bites resulting in various orthopedic problems (Doijode, 2018) [7]. In general, open reduction method of anatomic reconstruction requires wide exposure of the fracture site, which often results in substantial soft tissue trauma in the region of the fracture and can devascularize fracture fragments. Disruption of the extra osseous blood supply can prolong fractures healing and predispose to infection. Internal plating for stabilizing of long bone fractures continue to evolve to provide approaches, which minimize the iatrogenic trauma associated with surgery.
Emphasis has shifted from obtaining anatomic reconstruction and absolute stability using open reduction technique to minimally invasive technique for anatomic alignment and appropriate stability of the fractured bone with minimal osseous and soft tissue trauma associated with surgical intervention. In small ruminants newer and less invasive plating techniques have been developed to decrease the incidence of complications and to improve the functional outcome.
Minimally invasive plate osteosynthesis (MIPO) involves making small plate insertion incision remote to the fracture site through an epiperiosteal tunnel made between these incisions. The plate was introduced from either the proximal or the distal incision (Guiot and Dejardin, 2010). The MIPO technique decreases iatrogenic periosteal vascular disruption associated with plate application and may be advantageous when plating long bone fracture in small ruminants.

Materials and Methods
The present study on "Clinical study on efficacy of minimally invasive plate osteosynthesis (MIPO) in long bone fracture repair in small ruminants" was conducted on six goats of either sex, which were presented to the Teaching Veterinary Clinical Complex, College of Veterinary Science, Rajendranagar, Hyderabad. The cases presented with the history of trauma and the symptoms suggestive of diaphyseal fracture of tibia and metatarsus were selected for the study. The details of incidence of fractures in small ruminants were obtained based on species, sex, age, body weight, bone involved, type of fracture, nature of fracture, site of fracture and etiological factors. Goats presented with lameness were subjected to detailed physical, clinical and orthopedic examination. On clinical examination, the goats were examined for loss of function, abnormal mobility, deformity or change in the angulation of the affected limb, local

swelling, pain, crepitation, infection and exudates at the site of fracture.

Following initial clinical assessment radiographs on medio-lateral and cranio-caudal views for tibia and medio-lateral and dorso-plantar for metatarsus were taken for the confirmation of nature of fracture, soft tissue involvement and types of fracture in all the animals.

A total of six goats with fractures of either tibia or metatarsus were treated in the present study with MIPO. Of the six cases, two were fractures of tibia and four were of metatarsal fractures.

Anaesthesia was induced with intramuscular administration of Xylazine hydrochloride[1] at a dose rate of 0.1mg per kg and Ketamine hydrochloride[2] at the dose rate of 4 mg per kg body weight. After induction, anaesthesia was maintained with intravenous regional anaesthsia with 2% Lignocaine hydrochloride[3] at a dose rate of 2.5 mg per kg body weight. The surgical site was prepared aseptically by clipping the hair and scrubbing with 7.5% w/v Betadine [4] surgical scrub solution.

1. Xylazine hydrochloride (Inj. Xylaxin, Indian Immunologicals, Hyderabad),
2. Inj. Ketamine hydrochloride (Aneket, Neon Laboratpries Ltd)
3. Inj. Lignocaine hydrochloride (Lox 2%, Neon laboratories Ltd)
4. Betadine Surgical Scrub-Win-Medicare Pvt. Ltd, New Delhi.

The animal was positioned in dorsal recumbency with the affected limb was suspended from the intravenous infusion stand. The limb was pulled up sufficiently tight to allow the limb to be suspended by a portion of animal's weight.

A standard orthopaedic set which included Gelpi retractor, periosteal elevator, reduction forceps, Hohman’s retractors, bone holding forceps, hand drill, low power electric drill, bone cutter, wire pliers cum cutter along with a general surgical instrumentation set. The general surgical instruments set which included a long blunt curved (10 inch) metzenbaum scissors and AO/ASIF plate instrumentation set were used in the study.

Special instruments for Locking Compression Plates (LCP) application include *viz*., plate benders, drill guide (neutral and loaded ends), modified drill sleeve for LCP (2.7mm, 3.5mm and 4.5mm), drill bits (2.2 mm 3.0 mm and 4.0 mm), depth gauze (2.7 mm, 3.5 and 4.5 mm), locking screws and screwdriver were used in the study (Fig.1). The affected limb was bandaged using sterile bandage from joint below to the fracture and up to the hoof region and surgical site draped as per standard protocol. Surgical site was swabbed with 70 per cent alcohol.

Stainless steel LCPs with combination holes which allow placement of standard cortical and cancellous bone screws on one side or threaded conical locking screws on the opposite side of each hole were used in the study (Fig.2).

The required bone plates and screws were selected by careful reading of the radiographs. Locking Compression Plates of 6 holes 2.7 mm, 7 holes 3.5 mm and 9 holes 4.5 mm were used in the present study. Fully threaded 2.7 mm, 3.5 mm and 4.5 mm cortical locking screws were used. The length of the screws was determined by measuring the thickness of the bone from the anterioposterior radiographs before surgery and confirmed during surgery with the use of a depth gauge. Care was taken to ensure that the screw diameter did not exceed 40% of the diameter of the fractured diaphyseal as measured on the anterio-posertior radiographs.

Indirect fracture reduction technique as suggested by Peirone *et al*., (2012) [19] with hanging limb technique was used while performing MIPO since the fracture site was not exposed.

A medial surgical approach was used for MIPO in cases of fractures of tibia and cranial approach was used in metatarsal fractures. With the limb hanging, 2 to 4cm size of skin incision was made at distal part of fracture site and with the help of a metzenbaum scissors a subcutaneous and epiperiosteal tunnel was made. Then the metzenbaum scissors was passed through the tunnel and at the proximal tibia/ metatarsal a skin incision of 2 to 4 cm size was made directctly over the scissors. These skin incisions were made to facilitate the passage of the LCP plate. The fracture was then reduced with the objective of achieving a correct spatial alignment of the tibia/metatarsal bone.

After limb alignment and the fracture reduction was assessed and considered satisfactory, the LCP was inserted through the distal incision and advanced along the medial surface of the tibia through the epiperiosteal tunnel until the end of the plate was appropriately positioned. Similarly a 0.5 mm skin incision was made directly over the proximal most holes in the LCP and another screw was then inserted into the proximal tibial fragment. The screws were tightened securely after the limb alignment and fracture reduction was considered satisfactory. Additional screw was then sequentially inserted into both the most proximal and the most distal holes in the bone plate through the stab incision made directly over the holes in the LCP. The incisions were closed using across mattress suture using polyamide No.2-0. The entire procedure took about 15-20 minutes to accomplish in all cases (Fig.3 and 4).

The animals were kept under observation on the floor in a well-ventilated room with its neck in extended position until complete recovery from anaesthesia. The animal’s movement was restricted until complete recovery. A modified Robert jones bandage was applied from digits up to stifle joint for 2 days over the antiseptic dressing to prevent postoperative swelling of the limb.

Postoperatively, the site of operation was covered with sterile gauze which was impregnated with 5% povidone iodine solution. Over this a thick layer of cotton wrap was applied. This was covered with sterile gauze bandage and finally surgical tape was applied. Postoperatively, Inj. Ceftriaxone (Intacef[-1]) and Inj. Meloxicam (Melonex[-2]) were administered at a dose rate of 20 mg/kg and 0.2 mg/kg respectively intramuscularly for five days. Animals were allowed for limited movement to walk for 4-6 weeks. Passive exercises of the affected limb were performed 2 to 4 times daily during the convalescent period. Sutures were removed on the 10 post operatively day.

Clinical evaluation was carried out on every alternate day to check for the presence of swelling, exudation and weight bearing in all the goats. The post-operative day on which the goat started bearing weight was noted and graded. The appearance of the suture site was also examined on every alternate day until the suture was removed. After suture removal, the goat was examined once in a week until fracture healing was considered satisfactory.

1. Inj. Intacef - Intas Pharmaceutical Ltd Ahmedabad, India (Ceftriaxone Na)
2. Inj.Melonex- Intas Pharmaceutical Ltd, Ahmedabad, India (Meloxicam)

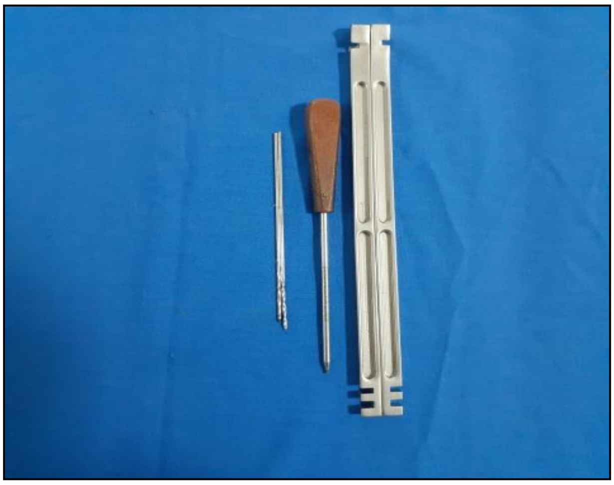


Fig 1: Special instrument like plate benders, Screw driver, Drill bits

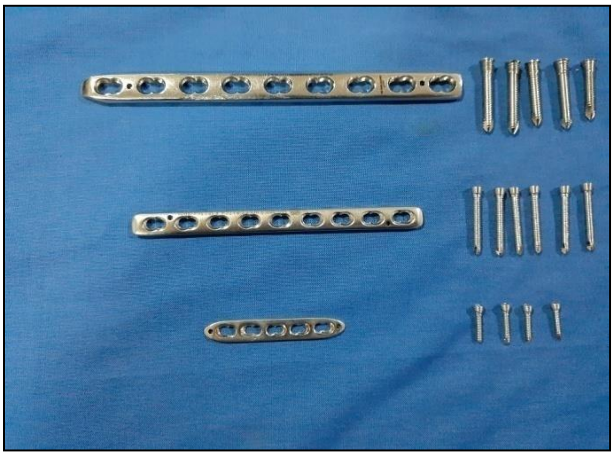


Fig 2: Different size of LCP Plates and Screws

Fig 3: Inserting 3.5 mm LCP plate from distal to proximal skin incision in tibial fracture repair with MIPO

Fig 4: Inserting 3.5 mm LCP from distal to proximal skin incision in metatarsal Fracture Repair in a Goat with MIPO

A lameness grade was assigned on the basis of severity of clinical signs on preoperatively and on1st, 7th, 14th, 30th and 60th postoperative day all animals were assessed to response to the treatment. Weight bearing was graded as follows (Vasseur *et al.*, 1995) [29].

Table 1: Lameness grading (Vasseur *et al*., 1995) [29]

Lameness Grade	Attribute
I	Normal weight bearing on all limb at rest and when walking
II	Normal weight bearing at rest, favours affected limb while walking
III	Partial weight bearing at rest and while walking
IV	Partial weight bearing at rest and does not bear weight on affected limb walking
V	Does not bear weight on limb at rest or while walking

Functional outcome was evaluated on the 60th postoperative day and categorized as excellent, good, fair and poor in all the animals (Clark, 1986). The assessment was subjective and based on individual evaluation.

Excellent	: No lameness compared to the dogs opposite limb, no post operative Complication
Good	: Moderate occasional lameness, does not require treatment, no Postoperative complication
Fair	: Persistent severe lameness may require revision surgery

Plain radiographs of anterio-posterior and medio-lateral views in case of Tibial fracture and medio-lateral and dorso-plantar views in case of metatarsal fractures were obtained immediately after surgery and on 7th, 15th, 30th, 45th and 60th postoperative days to assess the alignment of fracture fragments of the bone, stability of the implant and osteosynthesis in all the cases.

The radiographic evaluation of apposition and alignment of fractures on immediate postoperative day and follow-up radiographs on 7th, 15th, 30th, 45th and 60thday. Score for apposition and alignment (0-3) was given as follows (Cook *et al*., 1999) [6].

Table 2: Radiological scoring (Cook *et al.*, 1999) [6].

Radiological Score	Attribute
0	Complete radiographic healing
1	Appropriate progression towards healing, but not completely
2	Inappropriate progression towards healing
3	No evidence of healing, failure

Intra-operative complications like difficulty in fracture reduction, lacunae in application of MIPO technique if any were recorded. Postoperative complication slike plate bending and implant failure and wound infection if any in the operated animals were recorded.

The implants were left in situ even after clinical union in all the cases when there were no complications. The Implant was removed under general anaesthesia in a case of metatarsal fracture due to failure of the implant.

Results and Discussion

In the present study MIPO was applied to 6 goats with long bone fractures. Out of 6 goats, 2 goats were of tibial and 4 were of metatarsal fractures. This may be due to the cause of fracture ie., automobile accidents. The metatarsal bone has got the highest incidence of all long bone fractures in the study. This finding differs with the report of Gupta (2015), Kumar (2011) [15] and Singh *et al.* (2017) [24]. All fractures were closed except one, which was an open fracture.

Among the 6 cases, 3 cases had fractures on the left side and 3 cases had fractures on the right side. This may be due to the urban location of the goats presented for the study as they are more prone to automobile accidents.

In the present study, the highest fractures occurred in hind limb (tibial bone, metatarsal bone). This may be due to the cause of fracture ie. automobile accidents (Aithal *et al.*, 1998 and Singh *et al*., 2017) [2, 24]. Among the 6 cases of long bone fractures, 1 case (16.66%) was of mid shaft fracture and other 5 cases (83.33%) were of distal diaphyseal fractures (Gupta, 2015).

The highest incidence of fracture of long bones was seen infemale goats, 4, (66.66%), whereas the lowest incidence was recorded in male goats, 2, (33.33%). This may be due to the location of the goats presented for the study (in the urban area).

The age of the goats presented with fractures of tibia and metatarsal bones ranged from 4 months to 24 months with a mean age of 10.33 ± 3.13 months. Majority of the goats presented for the study were at an young age below one year (Singh *et al.*, 2017, Gupta, 2015 and Kumar, 2011) [24, 15].

The body weights ranged from 6 to 36 kg with a mean body weight of 15.54 ± 4.75 kg. The goats were presented for treatment between 2 to 5 days with a mean of 2.83 ± 0.47 days after sustained fractures (Table.3).

The incidence of fractures based on etiology was automobile accident 3 (50.00%), by falling from height 2 cases (33.33%) and by leg struck in gate grills (16.66%). The major cause due to automobile accidents may be because of urban location and more number of automobiles in the city (Singh *et al.*, 2017) [24].

The clinical signs of fracture were sudden onset of pain and lameness immediately after a traumatic injury. The other symptoms include swelling, dangling of the limb, non-weight bearing, abnormal angulation of the limb at the fracture site and crepitation at the site of fracture on physical palpation (Piermattei *et al*., 2006 and Johnson, 2007) [20, 13].

The location of fracture among these 6 cases, 1 case had midshaft fracture (16.66%) and 5 cases had distal diaphyseal fractures (83.33%). (Singh *et al.*, 2017 and Gupta, 2015) [24].

Among the 6 cases of hind limb fractures 4 cases had short oblique (66.66%), one case had comminuted fracture (16.66%) and othre case had transverse fracture (16.66%) (Table. 4). The high incidence of oblique fracture might be due to a force less than optimal breaking force on bone, acts tangentially, it gets distributed un-proportionately with more force on near cortex and less force on far cortex leading to break of the nearby cortex and tear in the far cortex, thus creating oblique fracture in goats (Kumar, 2007) [16].

Hanging limb technique was adapted to enable fracture reduction (Pozzi and Lewis, 2009, Guiot *et al.*, 2010, Hudson *et al*., 2012, Pozzi, 2017 and Townsend and Lewis, 2018) [22, 12, 26]. The medial approach for tibia and cranial approach for metatarsal fracture repair with MIPO in the present study found satisfactory

LCPs of 2.7 mm with 6 holes were used in four cases and 3.5 mm LCP with 7 holes was used in the one case. LCP of 4.5 mm with 9 holes was used in the other case. The LCPs used in the present study based on the requirement were found satisfactory. The plates were pre-stressed or contoured to the bone (Williams and Schenk, 2008, Guiot and Dejordin, 2012 and Hudson *et al*., 2012) [30, 11, 12]. Stainless steel 2.5 mm, 3.5 mm and 4.5mm locking screws of varying lengths were used in the present study. The screws provided a secure screw/ plate construct. The self-tapping flutes in the screw tip eliminated the need to tap the bone after drilling. Minimally Invasive Osteosynthesis Technique with LCPs permitted functional realignment of large bone fragments with minimal surgical invasiveness and shorter operative time. The limited approach offered fragment realignment and reduced surgical trauma. All the plates were applied in a bridging fashion as suggested by Hudson *et al*. (2009) [13].

In one of the goat with fracture of metatarsal, plate dislodgement was seen on the 30thpost-operative day due to jumping of the animal from height. Consequently, there was loosening of screws and breakdown of fracture fixation because of which the goat had to be operated on for a second time to remove the plate. This goat was applied coaptation splint.

Post-operatively, lameness grade showed gradual improvement to normal weight bearing over the period of study (Fig.5and 6). The lameness grade was carried out in accordance with the protocol developed by Vasseur *et al.* (1995) [29]. Normal weight bearing on all the limbs at rest and while walking was graded as I (as seen between 7th to 30th days) and this was attributed to adequate fracture reduction with LCP load sharing between implant and bone and minimal disruption of the soft tissue. In the present study, all the goats showed partial weight bearing from the 1st post-operative day. Full weight bearing was observed between 7th to 30th days with a mean of 13.6 ±4.11 days (Table.5).

In the present study, the LCPs showed remarkable improvement with normal limb function and maintaining good implant stability throughout the treatment period without any complications in five out of the six goats (Aguila *et al*., 2005, Florin *et al.*, 2005, Sod *et al.*, 2008, Uhl *et al.*, 2008 and Uhl *et al.*, 2013) [1, 8, 25, 28, 27]. Plate dislodgement with screw loosening was seen in one goat due to a second trauma to the already operated bone. Proper placement of LCP, apposition and alignment of the fracture fragments was recorded immediately by post-operative radiographs and proper application of the implant. While the patient remained anaesthetized post-operatively, radiographs should be taken to verify fracture reduction, implant position and placement and joint alignment. Radiographic evaluation was also carried out on 7th, 15th, 30th, 45th and 60th postoperative days to assess the status and condition of apposition and alignment, angulation, apparatus, activity and architecture (Langley-Hobbs, 2003) [17]. Fracture healing is a process of bone regeneration. It is divided into well documented stages: inflammatory, connective tissue and fibro-cartilage formation (soft callus), bony bridging or mineralization (hard callus) and remodeling (Aron, 1995) [3]. In the present study, fracture healing was scored based on callus formation and/ or elimination of the fracture line or gap as recommended by Cook *et al*. (1999) [6] (Table.6). All the fractures except in one goat where plate dislodgement was seen. Callus formation is the hallmark of secondary bone healing, which occurs under conditions of relative stability of the implant-bone construct (Claes *et al.*, 1997) [4]. The callus observed in the fractures stabilized using the MIPO technique suggested that this method provided both an appropriate vascular and mechanical environment to stimulate external callus formation as also stated by Claes *et al.* (2002) [5]. On the 15thpost-operative day, radiographic examination revealed a large sized callus bridging the fracture site with radiolucent fracture line still discernable. Radiographs obtained on the 30thpost-operative day revealed a much smoother, decreasing in size and opaque callus with faintly visible fracture lines. By the end of the 45thday, recheck radiographs showed slow obliteration of fracture line with bony callus bridging the fracture area, while 60thday recheck radiographs revealed complete radiological union in five cases (Fig. 7 and 8). The implants were left in situ even after clinical union in all the cases when there were no complications (Schmokel *et al*., 2007) [23]. In the present study, LCP was removed in one goat with metatarsal fracture after 30th day because a part of the plate was exposed as a result of laceration to the site where plate was applied.

No other complications observed except the plate dislodgement with screw loosening seen in one goat with fracture of metatarsal on 30th postoperative day due to jumping of the animal from height. The implant removal was considered in this case.

Table 3: Clinical history of the caprine selected for study

Case no	Breed	Age	sex	Body Weight (in kg)	Cause of injury	Days Since Injury
1	**Non-descript**	**4 months**	**M**	**6.0**	**Automobile Accident**	**5**
2	Non-descript	4 months	F	6.0	Fall from height	2
3	Non-descript	6 months	M	12.0	Leg struck In gate grill	3
4	Non-descript	6 months	F	11.25	Automobile Accident	2
5	Non-descript	18 months	F	22.0	Automobile Accident	2
6	Non-descript	24 months	F	36.0	Fall from height/hitting	3
Mean		10.3±3.13		15.54±4.75		2.83±0.47

Table 4: The details regarding the fractures encountered in all six goats

Case No	Limb affected	Bone involved	Open/ Closed	Location of Fracture	Types of Fracture
1	Left hind limb	Metatarsal	Open	Distal Diaphyseal	Short oblique
2	Right hind limb	Metatarsal	Closed.	Distal Diaphyseal	Short oblique
3	Right hind limb	Metatarsal	Closed	Distal Diaphyseal	Short oblique
4	Left hind limb	Metatarsal	Closed	Distal Diaphyseal	Complete Transverse
5	Left hind limb	Tibia	Closed	Distal Diaphyseal	Comminuted
6	Right hind limb	Tibia	Closed	Mid- shaft	Short oblique

Table 5: Post-Operative Details of Weight Bearing/Lameness

Case No	Pre- operative	Postoperative weight bearing at the end of					Complete weight bearing seen on
		Day 1	Day 7	Day 15	Day 30	Day 45	
1	V	IV	III	II	I	I	15thday
2	V	IV	III	III	II	I	30thday
3	V	IV	III	II	Plate dislodgement		Non-union treated By alternate ways
4	V	IV	II	I	I	I	7thday
5	V	IV	II	I	I	I	15thday
6	V	IV	III	II	I	I	15thday
Mean							13.6±4.11

I-Normal weight bearing on all the limb at rest and while walking, II-normal weight bearing at rest, favours affected limb while walking,-III-partial weight bearing at rest and while walking, IV-partial weight bearing at rest; does not bear weight on affected limb while walking V-does not bear weight on limb at rest or while walking.

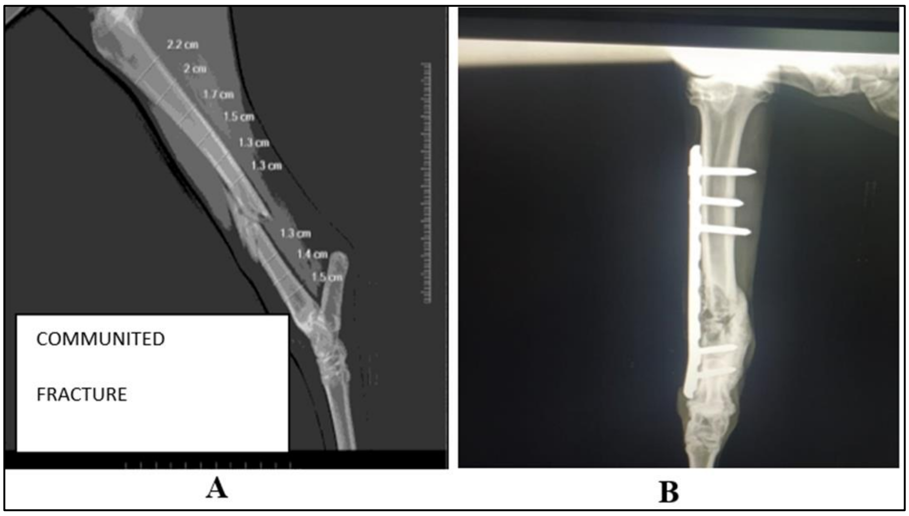
Table 6: Post-Operative Details of Radiological Scoring

Case No.	Pre-operative	Post-operative radiographic healing at the end of			
		Day 15	Day 30	Day 45	Day 60
1	3	1	1	1	0
2	3	1	1	1	0
3	3	1	Plate dislodgement		0
4	3	1	1	1	
5	3	1	1	1	0
6	3	1	1	1	0
Mean		1.00±1.1	1.16±0.9	0.80±0	

0-Comlete radiographic healing I- Appropriate progression towards healing, but not completely healedradiographically, 2-Inappropriate progression toward healing, 3- No evidence of healing, failure.

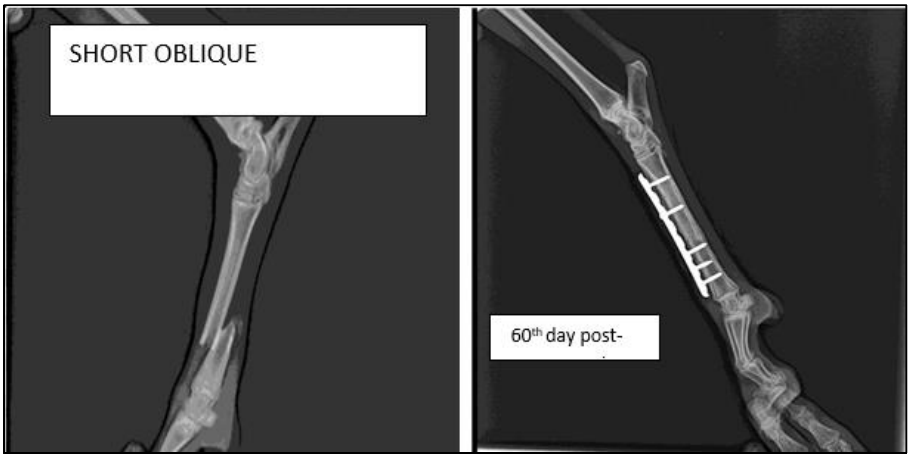
Fig 5: Progressive weight bearing in a goat during the postoperative period of tibial fracture repair with MIPO

Fig 6: Progressive weight bearing in a goat during the postoperative period of metatarsal fracture repair with MIPO.



Note. A. Radiograph showing comminuted fracture of tibia at distal third of the bone
B. Radiographs showing showing proper alignment, stable fiation of fracture fragments, progressive callus formation and cortical continuity at the posterior aspect of the bone at the fracture site.

Fig 7: Pre and Post-operative Radiographs of tibiall fracture repair with MIPO in a goat



Note. A. Radiograph showing short oblique fracture of metatarsal bone at distal third
B. Radiographs showing showing proper alignment, stable fiation of fracture fragments, progressive callus formation and cortical continuity at the posterior aspect of the bone at the fracture site.

Fig 8: Pre and Post-operative Radiographs of metatarsal fracture repair with MIPO in a goat

Conclusion
MIPO technique using LCPs provided good apposition and alignments of the fracture fragments. Healing was by callus formation. Satisfactory healing and limited complications were observed in the clinical study, suggesting that management of metatarsal and tibial fractures using MIPO is an effective and safe alternative to conventional fracture fixation.

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