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Clinical study on the use of Titanium Dynamic Compression Plate (Ti-DCP) for repair of femur fractures in dogs

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Abstract
The current study was undertaken to evaluate the clinical efficacy of Titanium Dynamic Compression plate for repair of femur fractures in dogs. This study was conducted on six dogs presented with fractures to the Department of Veterinary Surgery and Radiology at the College of Veterinary Science, Hyderabad. The six cases of fractures were diagnosed by clinical signs, orthopaedic examination and survey radiography. The symptoms observed in the dogs presented for treatment were pain on manipulation, abnormal angulation and lameness immediately after trauma, swelling, non-weight bearing, dangling of the limb and crepitation at the fracture site. Pre-operative radiographic examination in plain orthogonal views, i.e., cranio-caudal and medio-lateral radiographs revealed diaphyseal fractures in all dogs. Pre-operative radiographs also showed the type of fractures as distal transverse fracture of femur in two dogs, mid shaft diaphyseal transverse femur fracture in two dogs, proximal oblique femur fracture in one dog and mid shaft oblique femur fracture in 2 dogs. All fractures are closed, three in right hindlimb and two in left hindlimb and one dog had bilateral femur fracture. These fractures were stabilized with 2.7 mm Titanium DCP in one dog and 3.5 mm Titanium DCP in five dogs. Good implant stability throughout the treatment period without any complications was achieved all dogs. In all six dogs in the present study showed partial weight bearing on the 1st post- operative day. All six dogs showed normal weight bearing at rest, the weight bearing of the affected limb while walking from 2nd Post-operative day in one dog, 3rd Post-operative day in one dog, 5th Post-operative day in two dogs, 7th Post-operative day in one dogs and 8th Post-operative day in one dog. All six dogs achieved complete weight bearing by 15th post-operative day. i.e. from Grade V to Grade I. The mean age of the all dogs to bear the complete weight on the affected limb were seen on 5.0±2.28 days. The radiographs obtained on 30th day Post-operative day revealed proper apposition, decreased fracture gap, appearance of progressive bridging callus with adequate radio-density in all 6 dogs, and on 60th day revealed continuity of complete corticomedullary cavity and compete bone formation without any complications with fast healing. Based on present study, it was concluded that Titanium Dynamic compression plating was successful in the treatment of femur fractures in dogs as it is lighter in weight, had superior fatique and corrosive resistance, improved biocompatibility and lower young's modulus.

Keywords: Titanium-dynamic compression plate, internal fixation, biocompatibility, femur fracture repair

Introduction
The incidence of musculoskeletal injuries has been increasing constantly and among the small animal surgical cases the incidence of fractures was among the different species and reported it was highest in canines (35.66%) species, and pertaining to bones it was highest in femur bone (36.59%) [1]. Pelvic limb was the most affected limb (85.2%) among which femur bone (29.6%) was the most commonly involved bone followed by tibia-fibula (11.2%) in dogs [2].
The goal of fracture repair is to achieve complete bone healing with optimum function in as little time as possible. Modern fracture stabilization techniques and implants provide outstanding stability enabling a more rapid return to activity. The value of a rapid return to activity includes decreased muscle atrophy, decreased weight gain, maintenance of joint range of motion, minimization of decubital injuries, improved patient attitudes, and higher client satisfaction[3]. Various internal fixation devices have been used to repair the long bone fractures depending upon the stability required. Nonlocking bone plates achieve fixation of the fracture by friction generated by the application of a well-contoured plate to the bone surface with screws. When applied properly, bone plates effectively resist the axial loading, bending, and torsional forces acting on fractured bones [3].

Among the internal fixation techniques, bone plating was widely used because bone plates have the potential to restore rigid stability to the reconstructed fracture bone and also effectively resist the axial loading, bending and torsional forces acting on the fractures bones. Compared steel and titanium dynamic compression plate for internal fixation, the elasticity closer to that of bone can be obtained with titanium dynamic compression plate than stainless steel plate of same strength [4]. Titanium implants were having lower susceptibility to infection due to its biocompatibility [5]. Titanium and some of its alloys provide many advantages such as excellent biocompatibility, high strength-to-weight ratio, lower elastic modulus, and superior corrosion resistance, required for dental and orthopedic implants[6]. In comparison to stainless steel, titanium alloy has superior fatigue and corrosion resistance [7].

The dynamic compression plate (DCP) is a special plate developed by the AO group and it is standard plate type for many decades in the veterinary profession, the geometry of the DCP hole allows longitudinal angulation of screws of up to 25 degrees, and transverse angulation of up to 7 degrees. This can produce a challenge if a lag screw is being placed through the plate or if a screw must be aimed away from a fracture line. The amount of compression depends on the plate and screw size. Proper screw placement is ensured by using drill guides that centre the drill hole in either a loading position, approximately 1mm of compression is achieved for each screw tightened, wherea, in neutral position, approximately 0.1mm of compression is achieved. Adding to its material, titanium gives additional advantage such as excellent biocompatibility, high strength-to-weight ratio, lower elastic modulus, and superior corrosion resistance [7]. Due to paucity of literature on use of Titanium implants in dogs, the present study was undertaken to record the clinical efficacy of Titanium Dynamic Compression plating for repair of femoral fractures in dogs.

Materials and Methods

Anamensis

The dogs presented for treatment were 3 Mongrel dogs, 2 belongs to Labrador retriever and one Cocker Spaniel. The mean age of the dogs was 6.0±1.26 months with ranging from 4 months to 12 months. The body weights of the dogs ranged from 6-18 kg with a mean of 9.0±1.89 kg. The cause of fractures in this group was car accident in 3 dogs, auto accidents in 2 dogs and slipped on the floor in 1 dog. The fractures occurred in 4 male dogs and 2 female dogs. The mean time of gap between the time of fracture and treatment was 4.16±1.94 days with a range of 2- 7 days. The details were shown in table 1.

Table 1: History and Signalment of the dogs selected for the study in Group

S. No.	Breed of dog	Sex	Age in months	Body weight (KG)	Etiology of fracture	Days since fracture
1	Cocker Spaniel	Female	12	10	Hit by auto	2
2	Mongrel	Male	6	18	Hit by car	7
3	Labrador Retriever	Male	4	6	Slipped from the floor	3
4	Labrador Retriever	Male	4	6	Hit by car	4
5	Mongrel	Female	6	7	Hit by auto	3
6	Mongrel	Male	4	7	Hit by car	6
		Male -4, Female -2	6±1.26	9.0±1.89		4.16±1.94

Pre-Operative Observations

Pre-operative Clinical Observations

The six dogs presented for treatment femur fractures exhibited symptoms like sudden onset of pain and lameness immediately after a trauma. There were symptoms like swelling, dangling of the limb, non-weight bearing and abnormal angulation of the limb at the fracture site (Fig.1). In all the dogs, crepitation was noticed at the fracture site on physical manipulation. None of the dog had neurological deficit. All the six dogs had closed fractures.

Pre-operative Radiographic Observations

Two plain orthogonal views of medio-lateral and cranio-caudal radiographs of the affected limbs including the proximal and distal joints confirmed fractures[8]. Out of six dogs, the radiographs revealed distal transverse fracture of femur in two dogs, mid shaft diaphyseal transverse femur fracture in two dogs, proximal oblique femur fracture in one dog and mid shaft oblique femur fracture in 2 dogs. All fractures are closed, three in right hindlimb and two in left hindlimb and one dog had bilateral femur fracture. Pre-operative radiographs of the dogs with femur fractures were presented in fig.2 to 7. The details regarding the fractures encountered in all the dogs are presented in Table 2.

Table 2: Pre-operative Radiological Observations (Titanium dynamic compression plate)

Case No.1	Limb affected	Bone involved	Open or closed	Type /Location of fracture
1	Right hind limb	Right femur	Closed	Distal transverse fracture
2	Left hind limb	Left femur	Closed	Mid shaft oblique fracture
3	Right hind limb	Right femur	Closed	Mid shaft oblique fracture
4	Right hindlimb	Right femur	Closed	Mid shaft Transverse fracture
5	Both hind limbs	Right femur	Closed	Left femur- proximal oblique fracture
		Left femur	Closed	Right femur – transverse mid shaft fracture
6	Left hindlimb	Left femur	Closed	Distal transverse fracture

Fig 1: Non weight bearing of the fractured limb pre-operatively in group II dogs.

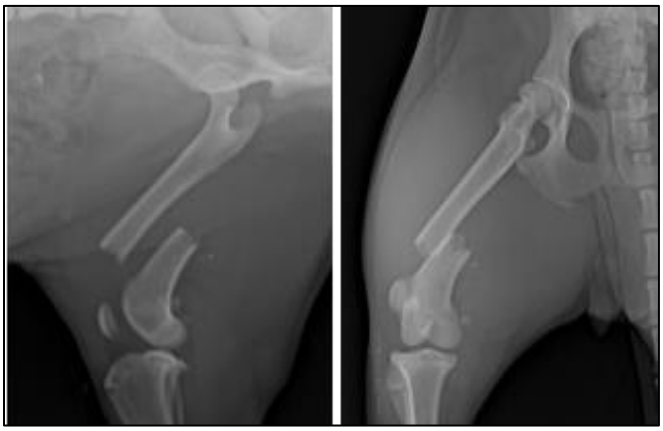

Fig 2: Skiagram showing Complete distal transverse fracture of femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 1, Pre-operative day

Fig 3: Skiagram showing Complete diaphyseal oblique fracture of femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 2, Pre-operative day

Fig 4: Skiagram showing Complete diaphyseal oblique fracture of femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 3, Pre-operative day

Fig 5: Skiagram showing Complete diaphyseal transverse fracture of femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 4, Pre-operative day

Fig 6: Skiagram showing Complete diaphyseal transverse fracture of right femur and proximal oblique fracture of left femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 5, Pre-operative day

Fig 7: Skiagram showing Complete distal transverse fracture of femur in a dog (medio-lateral and Cranio-caudal view) Group II - Case 6, Pre-operative day

Planning of Surgery

Measurements obtained from the pre-operative radiographs of the affected limb like length of the bone and transcortical diameter at different regions proved vital in selecting the length of the Titanium dynamic compression plates and the length of the screws to be used precisely in fracture fixation of femur Fig.8

Fig 8: Radiograph showing the length of fracture fragments in fracture limb in medio- lateral view and medio-lateral thickness of femur at different distances fracture limb in cranio-caudal view

Patient preparation

The affected limb was aseptically prepared by clipping the hair from a wide area surrounding the fracture site taking care to include upper and lower joints. The operative site was shaved and scrubbed using povidone-iodine surgical scrub, followed by the application of surgical spirit. Similarly, the skin was also prepared over the cephalic vein on both fore limbs for intravenous injections. Normal saline was infused intravenously throughout the duration of surgery.

Anaesthesia

Atropine sulphate at the rate of 0.04 mg/kg body weight was administered subcutaneously as pre-anesthetic medication followed 10-15 minutes later by xylazine hydrochloride at the rate of 1 mg/kg body weight intramuscularly [9]. Ten minutes later, general anaesthesia was induced with intramuscular injection of ketamine hydrochloride at the rate of 10 mg/kg body weight [10]. Following induction, the dogs were intubated with endotracheal tubes of suitable size. Anaesthesia was maintained with intravenous injection of propofol at the rate of 4 mg/kg body weight. Additional doses of propofol were also administered whenever necessary during surgical procedure through the intravenous line.

Positioning of the Animal

The dogs with fracture of femur was positioned in lateral recumbency with the fractured limb up.

Materials Used

Orthopaedic Instruments

A general surgical instrument set and orthopaedic instruments as needed for a particular procedure were used. Orthopaedic instruments including Gelpi retractors, Bone holding forceps, Hohmann's retractors, Senn retractors, eccentric and neutral drill guide, Orthopaedic hexagonal screw drivers, 2.0 mm and 2.7 mm Drill bits, Depth gauge and Low speed high torque electric drill were used for performing Titanium Dynamic Compression Plating.

Implants

Titanium Dynamic Compression plate were used in six dogs. Selection of appropriate size of Ti DCP was determined by the weight of the dog and pre-operative measurements in medio-lateral view for thickness and length of the plate by measuring the length and width of the femur. In the present study, 2.7mm, 8 holed Titanium dynamic compression plate (Fig.9 and 10) were used in one dog weighing 7 kg, 3.5 mm 6 holed Ti DCP used in 2 dogs weighing 6kg, 3.5mm 7 holed Ti DCP used in one dog weighing 10 kg, 3.5 mm 8 holed (2) Ti DCP in one bilateral femur cases weighing 7kg and 3.5mm 10 holed Ti DCP in one dog weighing 18kg. The results indicated that the use of 6 to 10 holes 2.7 mm and 3.5 mm Titanium Dynamic Compression plate and self tapping 2.7mm and 3.5 mm cortical screws varying from 16 mm to 30 mm in length were used in six dogs were found adequate without any complications. The design of study is given in table.3

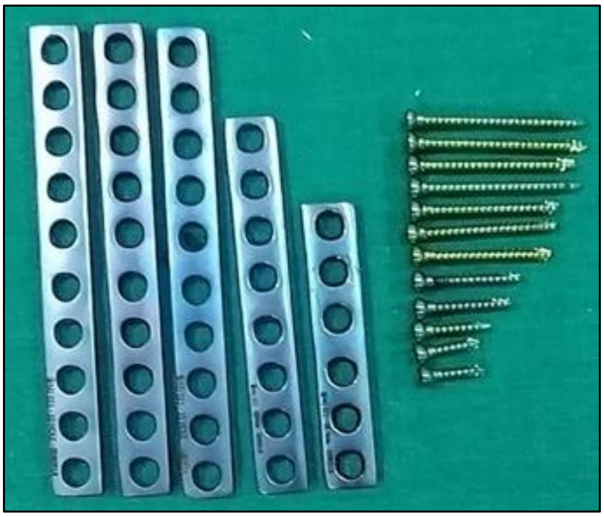

Fig 9: 3.5mm titanium dynamic compression plates and titanium self-tapping cortical screws used in group II

Fig 10: 2.7 mm titanium dynamic compression plates and titanium self-tapping cortical screws used in group II

Table 3: Clinical details of dogs (Titanium Dynamic Compression Plating Technique)

Case no.	Breed of dog	Sex	Age (m)	Etiology of fracture	Unilateral /bilateral	Type of fracture	Details of implant used	No of screws used 3.5 mm diameter
1	Cocker Spaniel	Female	12 months	Hit by auto	Unilateral Right femur	Distal transverse fracture	Titanium DCP 3.5 mm thickness 7 holes plate	6 self-tapping titanium cortical screws (16mm-2, 18mm-3, 20mm-1)
2	Mongrel	Male	6 months	Hit by car	Unilateral left femur	Mid shaft oblique	Titanium DCP 3.5 mm thickness 10 holes plate	8 self-tapping titanium cortical screws (18mm -2, 20mm-2, 26mm-2, 28mm-2)

						fracture		
3	Labrador Retriever	Male	4 months	Slipped from the floor	Unilateral right femur	Mid shaft oblique fracture	Titanium DCP 3.5 mm thickness 6 hole plate	5 self-tapping titanium cortical screws (16mm-1, 18mm-1, 22mm-3)
4	Labrador Retriever	Male	4 months	Hit by car	Unilateral right femur	Mid shaft Transverse fracture	Titanium DCP 3.5 mm thickness 6 hole plate	5 self-tapping titanium cortical screws (16mm-3, 18mm-1, 20mm-1)
5	Mongrel	Female	6 months	Hit by auto	Bilateral femur	Left femur- proximal oblique fracture	Titanium DCP 3.5 mm thickness 8 hole plate	5 self-tapping titanium cortical screws (22mm-2, 20mm-2, 18mm-1)
						Right femur – transverse mid shaft fracture	Titanium DCP 3.5 mm thickness 8 hole plate	6 self-tapping titanium cortical screws (22mm-4, 20mm-2)
6	Mongrel	Male	4 months	Hit by auto	Unilateral Left femur	Distal transverse fracture	Titanium DCP 2.7mm thickness 8 hole plate	7 self-tapping titanium cortical screws (24mm-1, 20mm-4, 18mm-2)
		Male -4 Female - 2	4-12 months		Left -3 Right-2 Bilateral-1			

Surgical Procedure

The cranio-lateral border of thigh approach was used for exposure of fractured diaphysis region of femur bone to perform bone plating using Ti-DCP (Fig. 11) [11]. Following the surgical exposure of the fracture site (Fig.12) as described, the fracture fragments were aligned and reduced to restore the length and correct rotational orientation (Fig. 13). Titanium dynamic compression plate was then placed over the bone and the plate was held in position with bone holding forceps (Fig.14). It was ensured that, the alignment was correct before securing the plate to the bone with cortical screws. The bone was drilled with 2.0 mm and 2.7 mm drill bit which corresponded with the inner core diameter of the screw using a low speed high torque electric drill. The length of the screws needed for application of Titanium dynamic compression plate in each patient was determined by measuring the transcortical diameter of femur different distances from the fracture site of respective bones from the pre-operative radiographs and was confirmed during the surgical procedure by using a depth gauge. A screw of suitable length was then placed at the drilled hole and tightened using a hexagonal orthopaedic screw driver until the taper end of screw exited the far cortex to secure the Ti-DCP plate to the bone. Bone plating was accomplished by insertion of additional screws in both proximal and distal fracture fragments leaving the fracture line (Fig.15).

Fig 11: Skin incision made from trochanter major to lateral condyle of femur

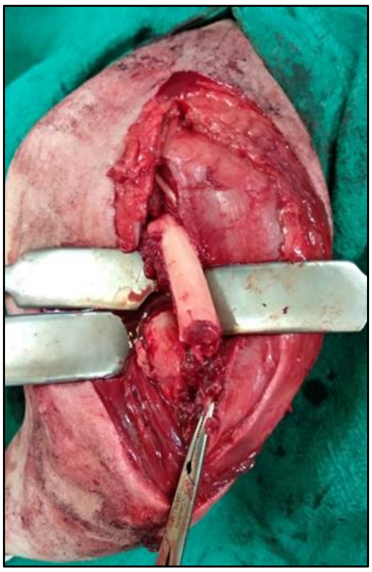

Fig 12: Femoral fractured fragments were exposed

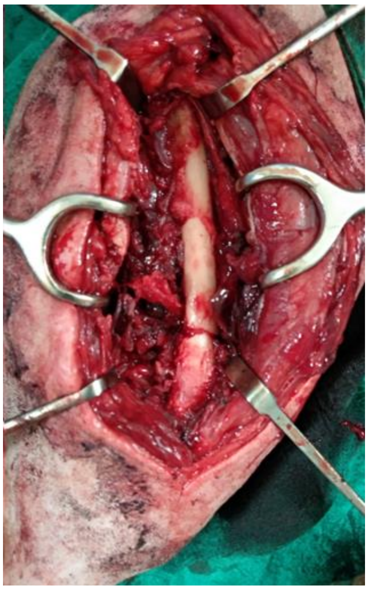

Fig 13: Fracture fragments were aligned and reduced to restore the length and correct rotational orientation

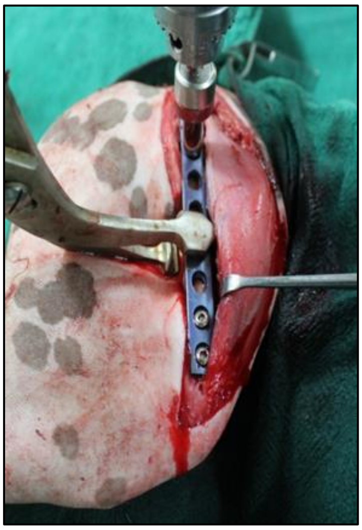

Fig 14: Titanium dynamic compression plate was then placed over the bone and the plate was held in position with bone holding forceps

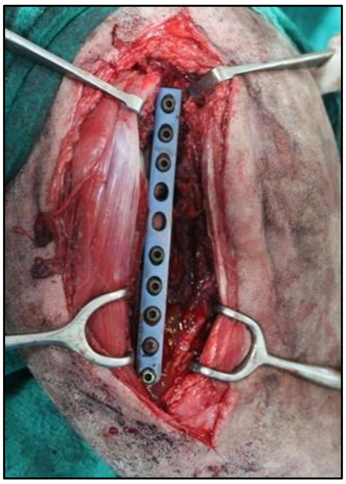

Fig 15: 3.5mm Titanium Dynamic compression plate used in this group of dogs

Closure of the incision
In case of femoral approach, the fascia lata was sutured with 2-0 polyglactin 910 in a simple continuous suture pattern (Fig.16). Subcuticular sutures were applied with 2-0 polyglactin 910 (Fig.17). Skin incision was closed with a row of cruciate mattress sutures of 2-0 polyamide (Fig.18).

Fig.16 Tensor fascia lata muscle being closed with simple continuous suture of 2-0 polyglactin 910

Fig 17: Subcuticular sutures were placed with 2-0 polyglactin 910

Fig 18: The skin incision was closed in a row of cruciate mattress sutures of 2-0Polyamide

Post-Operative Care and Management
The suture line was covered with a thin layer of sterile gauze bandage dipped in 5% povidone iodine solution. Over this, a thick layer of cotton pad was wrapped. It was then covered with gauze bandage and finally, a layer of surgical paper tape was applied. The dressing was replaced on every alternate day until the sutures were removed on the 12th post-operative day. Injection ceftriaxone sodium was administered at the rate of 25 mg/kg body weight as intramuscular injection for 7 days post-operatively. Injection meloxicam was administered once a day at the rate of 0.3 mg/kg body weight by intramuscular injection for 3 days post-operatively. Owners were advised to restrict the movement of the animal for the first 2 weeks of surgery and then to allow leash walking for the next few weeks.

Results
Clinical evaluation was carried out every alternate day to check for the presence of swelling, exudation and weight bearing in all the dogs. The appearance of suture line was also examined every alternate day until the sutures were removed. The post- operative day on which the dog started bearing weight was recorded and graded. After suture removal, the dogs were examined once in a week for the limb stability until fracture healing was considered satisfactory.

Post-Operative Clinical Observations
Dressing the surgical wound with 5% povidone iodine pads was found to be effective in keeping the site clean in all the dogs. Application of Robert-Jones bandage provided

satisfactory immobilization of the limb. The use of injection ceftriaxone sodium effectively prevented post-operative infection. The skin sutures were removed between 10th to 12th post-operative day in all the dogs. None of the dogs developed post-operative swelling and suture dehiscence and the surgical wounds healed well in all the dogs without any complications

Lameness grading

In all six dogs in the present study showed partial weight bearing on the 1st post- operative day. All six dogs showed normal weight bearing at rest, the weight bearing of the affected limb while walking from 2nd Post-operative day in one dog, 3rd Post-operative day in one dog, 5th Post-operative day in two dogs, 7th Post-operative day in one dogs and 8th Post-operative day in one dog. All six dogs achieved complete weight bearing. The mean lameness grades observed pre-operatively and on 1st day, 15th day, 30th day, 60th day and 90th day post- operatively were found to be 5.0±0.0, 3.16±0.98, 1.33±0.51, 1.66±0.81, 1.0±0.0 and 1.0±0.0 respectively. The mean age of this group of dogs to bear the complete weight on the affected limb were seen on 5.0±2.28 days. Different post-operative weight bearing of the affected limb in all six dogs were depicted in Fig. 20. The details of lameness grading [12] were presented in Table 4.

Table 4: Post-operative details of lameness grading

Case. No	Pre-operative	Post-operative weight bearing at the end of					Complete weight bearing seen on
		Day 1	Day 15	Day 30	Day 60	Day 90	
1	V	II	I	I	I	I	2nd day
2	V	III	II	I	I	I	7th day
3	V	III	I	I	I	I	5th day
4	V	III	I	I	I	I	5th day
5	V	V	II	I	I	I	8th day
6	V	III	I	I	I	I	3rd day
	5.0±0.0	3.16±0.98	1.33±0.51	1.66±0.81	1.0±0.0	1.0±0.0	5.0±2.28

Grade I- Normal weight bearing on all limbs at rest and while walking.
Grade II- Normal weight bearing at rest, favors affected limb while walking.
Grade III- Partial weight bearing at rest and while walking.
Grade IV- Partial weight bearing at rest; does not bear weight on affected limb while walking.
Grade V- Does not bear weight on limb at rest or while walking

Case. 1 2nd Post-operative day

Case.2 7th Post-operative day

Case.3 5th Post-operative day

Case.4 5th Post-operative day

Case.5 8th Post-operative day

Case.6 2nd Post-operative day

Fig 20: Showing first weight bearing of affected hind limb on different post-operative days in all six dogs.

Fig 21: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 1, Immediate post-operative day

Fig 22: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 2, Immediate post-operative day

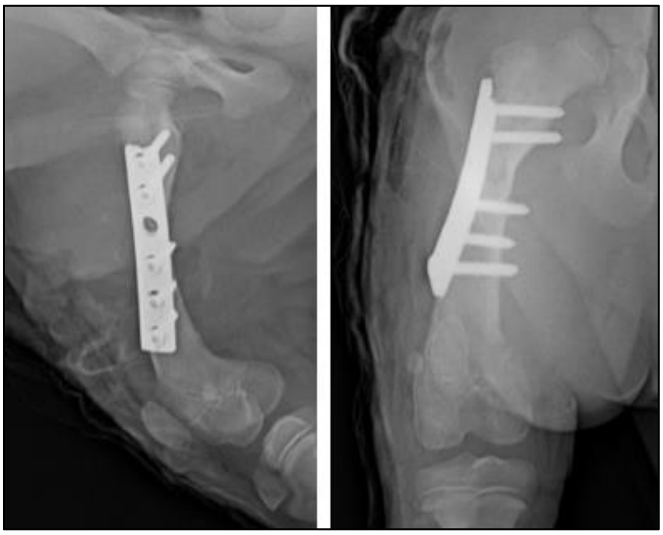

Fig 23: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 3, Immediate post-operative day

Fig 24: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 4, Immediate post-operative day

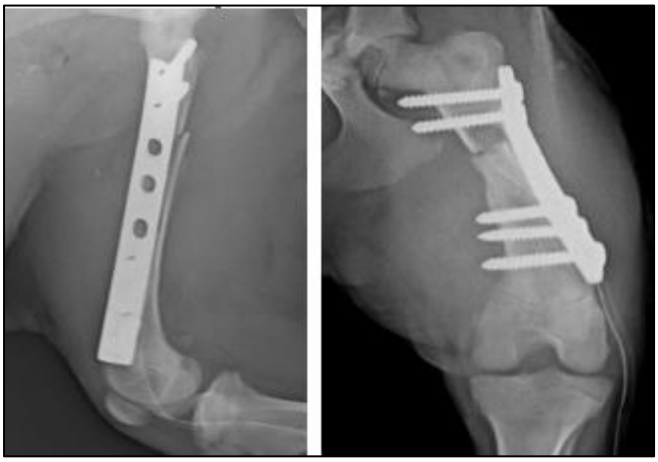

Fig 25: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 5, Immediate post-operative day

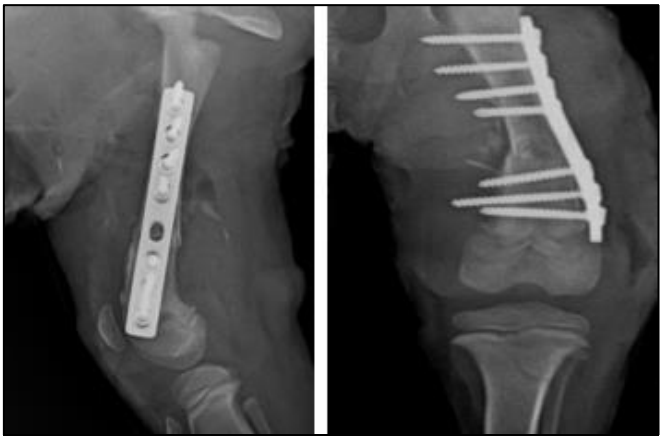

Fig 26: Skiagram showing apposition of fracture fragments (Medio-lateral and Cranio-caudal view) Group II- Case 6, Immediate post-operative day

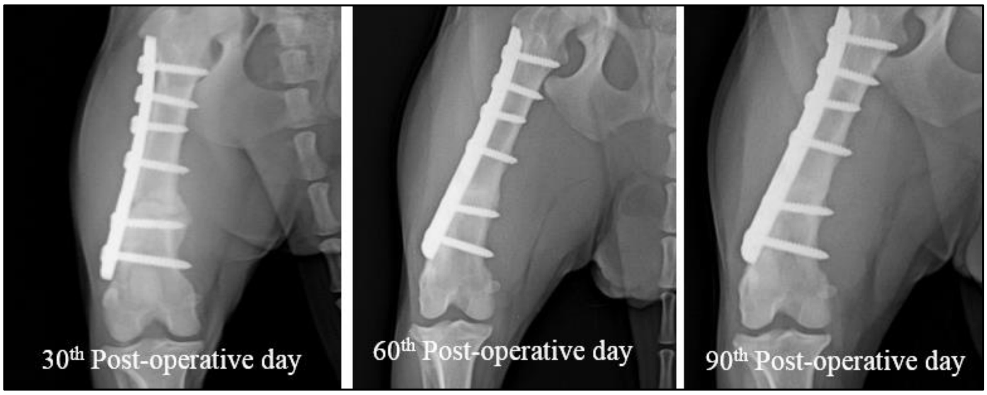

Fig 27: Skiagram showing progressive radiographic fracture healing in case 1

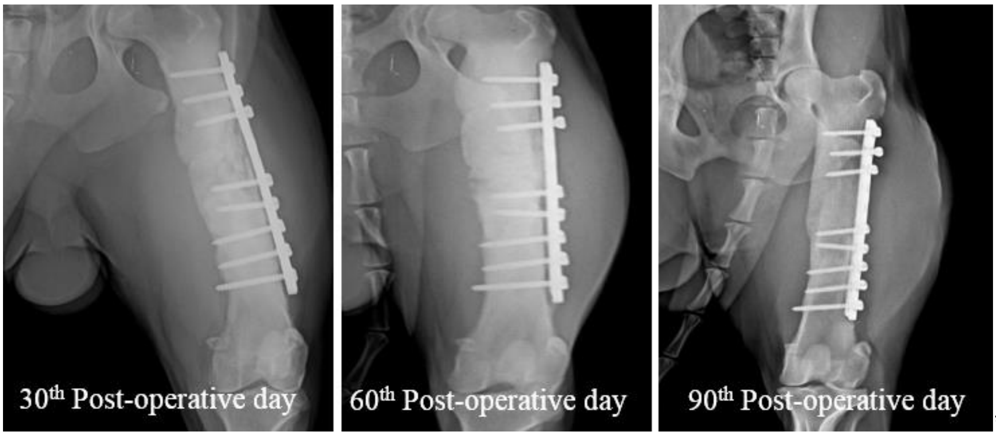

Fig 28: Skiagram showing progressive radiographic fracture healing in case 2

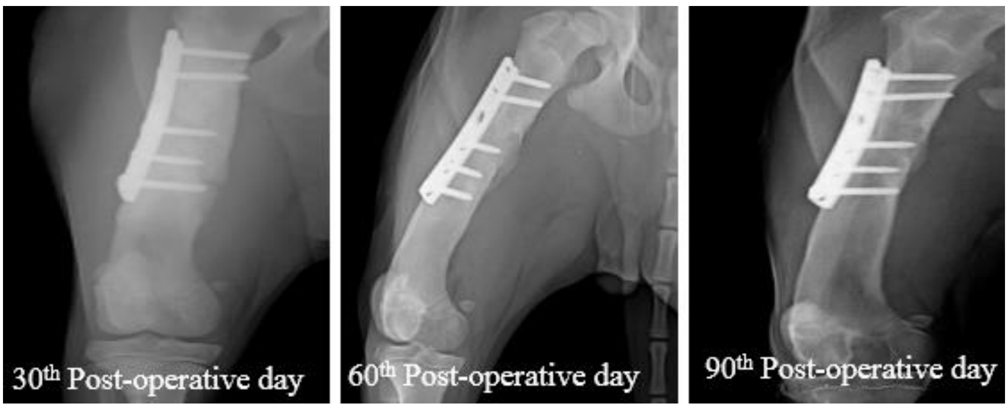

Fig 29: Skiagram showing progressive radiographic fracture healing in case 3

Fig 30: Skiagram showing progressive radiographic fracture healing in case 4

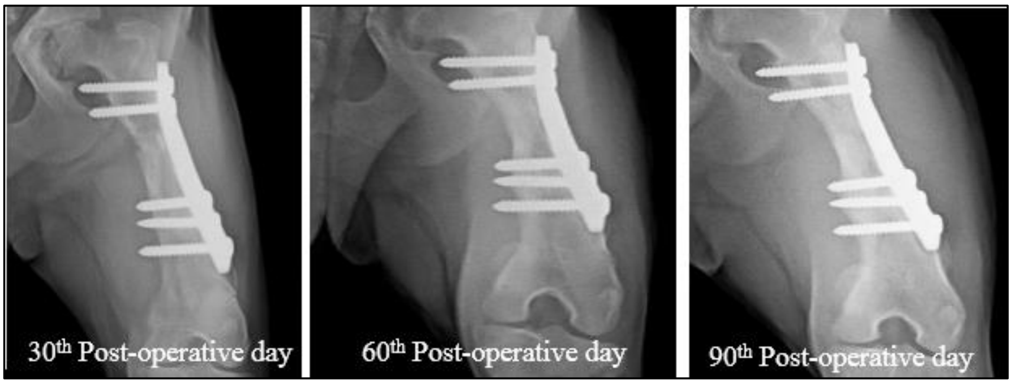

Fig 31: Skiagram showing progressive radiographic fracture healing in case 5

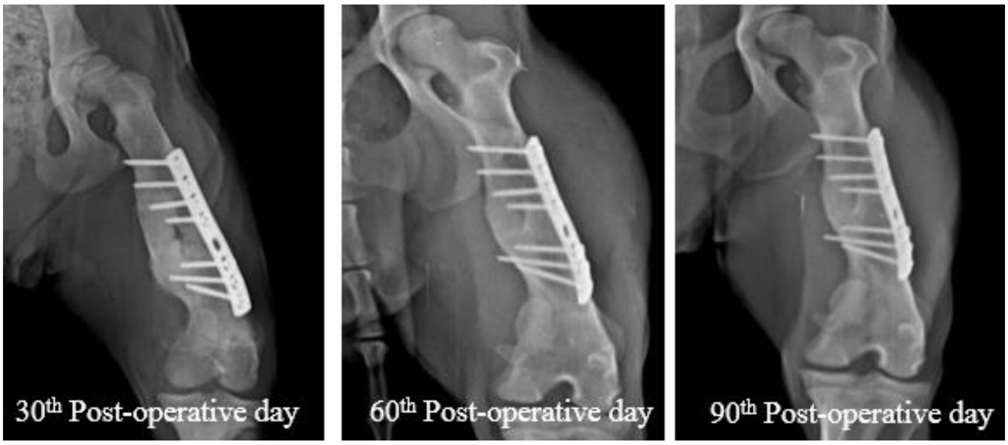

Fig 32: Skiagram showing progressive radiographic fracture healing in case 6

Post-Operative Radiographic Observations

Immediate Post-operative radiographic evaluation confirmed proper placement of Titanium dynamic compression plate with titanium cortical screws, and good apposition of the fractures fragments in all the six dogs (Fig.No.21 to 26). Immobilization was considered satisfactory in all cases in this group The radiographs obtained on the 15th Post-operative day revealed proper apposition and alignment of fracture fragments in all the six dogs and also presence of callus at the fracture site. The radiographs obtained on 30th day Post-operative day revealed proper apposition, decreased fracture gap, appearance of progressive bridging callus with adequate radio-density in all 6 dogs. By 60th post-operative day the fracture line disappeared and the callus became radio-dense with clear establishment of cortico-medullary canal in all 5 dogs. In one dog the presence a gap in the callus still under process of healing, the callus pointing to the restitution of cortio-medullary continuity well appreciated on the radiograph. It is observed that formation of callus, and restitution of the cortico-medullary canal is completed and which is well appreciated on a radiograph by 60th and 90th post-operative days respectively. The progressive radiographic fracture healing was showed in Fig. 27 to 32. In this group it is depicted fast healing on the radiographic evaluation [13] in all dogs without any complications in table 5.

Discussion

Lameness grading based on weight bearing was recorded in all cases pre-operatively, showed grade V lameness. Postoperatively, all 6 dogs progressed to grade I lameness by the end of 30th post-operative day and Post-operative radiographic evaluation confirmed proper placement of the plates and screws, apposition and alignment of the fracture fragments in all the six dogs[14]. Immobilization was considered satisfactory in all the cases. The plate length, size and position were appropriate in all the cases. Screw length, size and position were found to be appropriate in all the cases. Follow-up radiographs taken on 15th, 30th, 60th and 90th post-operative days revealed primary bone healing with minimal callus formation [15]. By 60th post-operative day the fracture line disappeared and the callus became radio-dense with clear establishment of cortico-medullary canal in all 5 dogs. In one dog the presence a gap in the callus still under process of healing, the callus pointing to the restitution of cortio-medullary continuity well appreciated on the radiograph. Good implant stability throughout the treatment period without any complications was achieved in all dogs and similar results was reported [16, 17, 18].

Conclusion

Based on present study, it was concluded that Titanium Dynamic Compression Plates (Ti-DCP) was successful for the repair of femur fractures in dogs and offered good recompense and remarkable improvement in the limb function, with good fracture stability till the completion of the bone healing in all six dogs. The application of Ti- DCP plates was found to be effective with additional features such as excellent biocompatibility, high strength-to-weight ratio, lower elastic modulus, and superior corrosion resistance. In this group of dogs with titanium dynamic compression plating technique, all six dogs had no complications, and no owner insisted for removal of the implant.

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