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A Comparative Study on Repair of Canine Femoral Fractures Using Titanium and Stainless Steel Intramedullary Interlocking Nail

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ABSTRACT

The present comparative clinical study in twelve dogs age ranged from 5 to 24 months. Six were male and six were female, among them 4 Mongrels (33.33%), two Labrador retrievers (16.6%), one each of Golden retriever (8.3%), German shepherd (8.3%), Mudhol hound (8.3%), Saint bernard (8.3%), Siberian husky (8.3%), and Pomeranian (8.3%). The body weight ranges from 11 to 42 kg. 50% of dogs had femur fractures due to automobile accidents, 33.33% had due to slipping on the floor, fallen from height (8.33%), fight between dogs (8.33%),and wild animal attack (8.33%). Lameness grading in the two groups pre-operatively showed grade V lameness. After surgical stabilization in group I (stainless steel IILN) the mean lameness grading score on immediate post operative day, 15th , 30th, 60th, and 90th post operative days were 3.16±1.2, 2.1±1.2, 1.6±6.2, 1.5±2.3, and 1.3±3.1 respectively. This showed gradual reduction in lameness grading score. In group II (Titanium IILN), the mean lameness grading score on immediate post operative day, 15th, 30th, 60th, and 90th post operative days are 2.8±3.3, 1.3±3.2, 1.16±2.6, 1.16±2.6 and 1.16±2.6 respectively. In the group II dogs, earlier weight bearing and normal limb function were recorded with a mean of 3.5±2.5 days in compared to group I having a mean of 6.0±2.5 days, thus lameness grading was superior in titanium group. The fracture healing by negligible callus in 10 dogs, two dogs with secondary callus formation. Radiological scoring in the two groups showed complete radiographic healing from 60th day to 90th day post-operatively without any disturbance in apposition, alignment, angulation and apparatus.

HIGHLIGHTS

- Titanium and Stainless Steel Intramedullary Interlocking Nail were used for the repair of femur bone.
- Showed complete radiographic healing on day 60th to 90th.

Keywords: Dog, Femur, Fracture, Intramedullary Interlocking Nail, Titanium, Stainless steel

Femur is the most highly loaded bone during weight bearing thus it is the most frequently fractured long bone in dogs comprising almost half of all long bone fractures (Piermatti and Flo, 1997). High velocity injuries are the most common type of trauma that causes femoral fractures in veterinary patients. The major etiologies explained as automobile accidents, traumatic injuries like fall, jumping from a height and pathological fracture incidents due to rickets, osteomalacia, and primary or metastatic bone tumors (Fossum, 2013 and Jagan Mohan Reddy, 2020).

An intramedullary pin acts as load sharer, they cannot

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provide sufficient stability in comminuted fractures leading to collapse at the fracture site (Srinivas *et al*., 2021) And it counteracts only bending forces while intramedullary interlocking nails resist both bending as well as torsional forces (Bernarde *et al*., 2001) and Jagan and Dilip 2021a).

Principal requirements for all the biomaterials used as implants, including metallics, plastics, and ceramics are presently understood to be corrosion resistance, biocompatibility, bioadhesion (bone ingrowth), biofunctionality (mechanical properties, including fatigue strength and Young's modulus) processability and availability. (Boyer, 2007). Amongst the metals, 316L stainless steel, cobalt chromium alloys, and titanium based alloys are the frontrunners in various orthopaedic applications like fracture fixation, hip joint replacement and dentistry (Kaur and Singh, 2019).

Stainless steel has the advantages of low cost, easy availability, acceptable biocompatibility. But the disadvantages includes the high modulus, low corrosion resistance and allergic reaction (Staiger *et al*., 2006).

Titanium and titanium based alloys are biocompatible, corrosion resistive, has high fatigue strength, low modulus, and light weight (40% less than stainless steel). But it has low wear resistance. Its application includes Total joint replacement and fracture fixation implants (Wang, 1996).

MATERIALS AND METHODS

The Dogs presented with the history and clinical signs of femur fracture were subjected to detailed physical, orthopaedic and radiographic examination to confirm the diagnosis of femur fracture. Of the animals screened twelve dogs with femur fracture, were selected and were divided into two groups randomly without any prejudicing over the fracture configuration and body weight of the dogs (Table 1).

The dogs presented for treatment in this group 1 were 2 Labrador retrievers, one each of Mudhol hound, Saint Bernard, German Shepherd and Mongrel. The mean age of the dogs was 23.5±5.10 months with ranging from 7 months to 36 months. The body weights of the dogs ranged from 18 to 42 kg with a mean of 27.5±3.5 kg. The cause of fractures in this group I was slipped in floor in 3 dogs, followed by Fight between dogs, wild boar attack an automobile accident in one each dog. The fractures occurred in 4 female dogs and 2 male dogs. The mean time of gap between the time of fracture and treatment was 4 days with a range of 2 to 7 days.

Table 1: Clinical history of cases presented in two groups

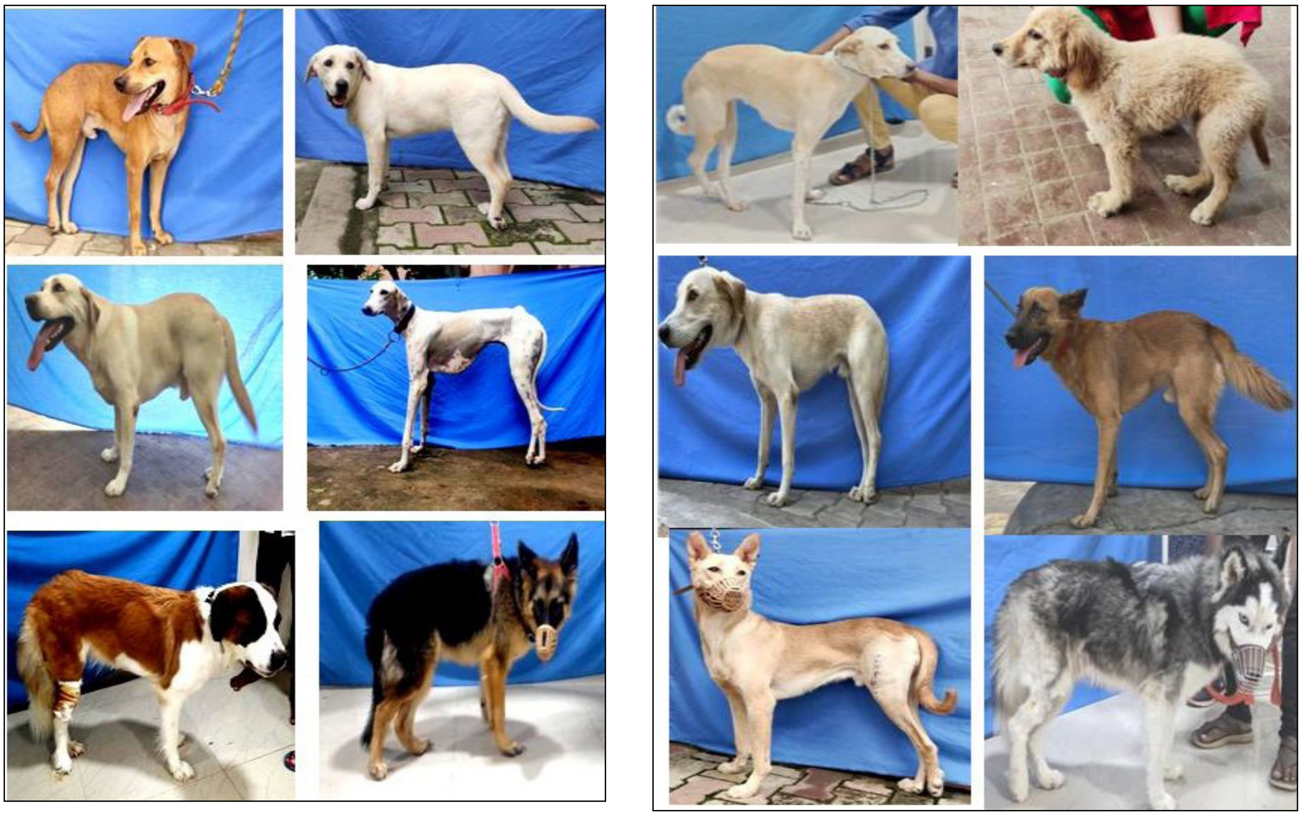
					Group 1			
Sl. No.	**Breed**	**Age (Months)**	**Sex**	**Body weight**	**Cause**	**Days since fracture**	**Unilateral/ bilateral**	**Limb affected**
1	Mongrel	18 months	Male	19kg	Fight between dogs	4	Unilateral	Right
2	Labrador retreiver	7 months	Female	18kg	Slipped in floor	6	Unilateral	Left
3	Labrador retriever	24 months	Male	42kg	Slipped in floor	7	Unilateral	Left
4	Mudhol hound	36 months	Female	20kg	Wild boar attack	3	Unilateral	Left
5	Saint bernard	20 months	Female	36kg	Slipped in floor	2	Unilateral	Right
6	German shepherd	36 month	Female	30kg	Automobile accident	2	Unilateral	Right
	Mean	23.5±5.10		27.5±3.5		4		
					Group_II			
1	Mongrel	12 months	Female	16 kg	Automobile accident	3	Unilateral	Right
2	Golden retriever	5 months	Female	6 kg	Slipped in floor	7	Unilateral	Left
3	Mongrel	8 months	Male	16kg	Automobile accident	4	Unilateral	Left
4	Pomeranian	18 months	Male	11kg	Automobile accident	3	Unilateral	Right
5	Mongrel	20 months	Male	20kg	Automobile accident	3	Unilateral	Left
6	Siberian husky	12 months	Male	18kg	Automobile accident	3	Unilateral	Right
Mean		12.5±5.10		14.5±3.65		3.83		

The dogs presented for treatment in this group II were 3 Mongrels, one each of Golden Retriever, Siberian Husky and Pomeranian. The mean age of the dogs was 12.5±5.10 months with ranging from 5 months to 20 months. The body weights of the dogs ranged from 6 to 20 kg with a mean of 14.5±3.65 kg. The cause of fractures in this group II was automobile accident in 5 dogs followed by slipping on floor in one dog. The fractures occurred in 4 female dogs and 2 male dogs. The mean time of gap between the time of fracture and treatment was 3.83 days with a range of 3 to 7 days. The details were shown in table 1.

The 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). Two plain orthogonal views of the affected limbs including the proximal and distal joints confirmed fractures (Guiot *et al*., 2012). The radiographs revealed proximal diaphyseal fracture in one dog (8.33%), mid diaphyseal fractures in eight dogs (66.40%) and distal diaphyseal fractures in three dogs (25%). The type of fractures were transverse fracture in three dogs (25%), oblique fracture in two dogs (16.66%), comminuted fracture in two dogs (16.66%) and spiral fracture in six dogs (50%) and all were closed fractures (Fig. 2). The details regarding the fractures encountered in all the dogs are presented in Table 2.

The length of the bolts needed for application of titanium IILN, in each patient was determined by measuring the medio-lateral thickness of fractured femur at different distances from the fracture site directly from the antero-posterior view and length and thickness of titanium interlocking nail was determined by measuring the medio-lateral radiographs respectively.

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. Atropine sulphate



Group 1 **Group 2**

Fig. 1: Preoperative non weight bearing of fractured hind limbs in dogs

Table 2: Fracture classification of femur in two groups

Group I			Group II		
Affected limb	**Fracture location**	**Type of fracture**	**Affected limb**	**Fracture location**	**Type of fracture**
Right	Mid diaphyseal	Closed complete spiral	Right	Middle diaphyseal	Closed complete comminuted
Left	Mid diaphyseal	Closed complete spiral	Left	Middle diaphyseal	Closed complete spiral
Left	Distal diaphyseal	Closed complete transverse	Left	Distal diaphyseal	Closed complete transverse
Left	Middle diaphyseal	Closed complete comminuted	Left	Distal diaphyseal	Closed complete transverse
Right	Middle diaphyseal	Closed complete spiral	Left	Middle diaphyseal	Closed complete oblique
Right	Proximal diaphyseal	Closed complete spiral	Right	Middle diaphyseal	Closed complete spiral

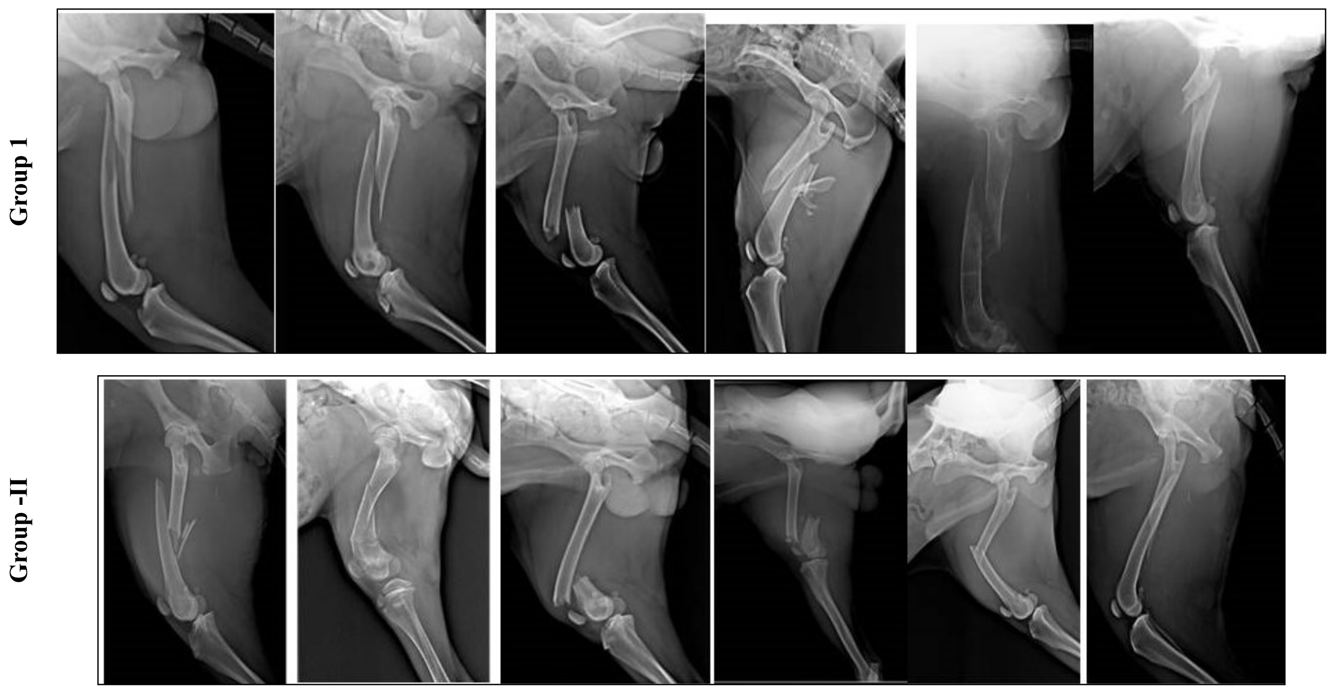


Fig. 2: Preoperative skiagram showing femur fractures in all cases (medio-lateral view)

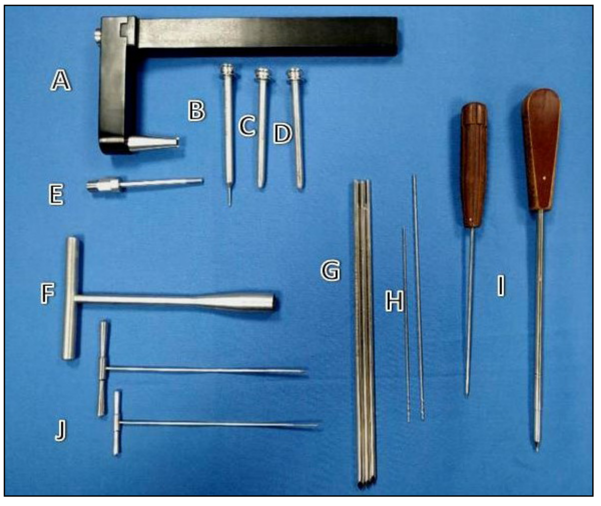
at the rate of 0.04 mg/kg body weight was administered subcutaneously as pre-anaesthetic medication 15 minutes later followed by combination of xylaxine at rate of 1 mg/kg body weight and ketamine at the rate of 10 mg/kg body weight intramuscularly. Ten minutes later, general anaesthesia was induced with intravenous injection of Propofol at the rate of 3 mg/kg body weight. Following induction, the dogs were intubated with endotracheal tubes of suitable size. Anaesthesia was maintained with isoflurane at the rate of 2.5 in 100% and during the surgical procedure. A general surgical instrument set and orthopaedic instruments were used along with the Interlocking Jig and its accessories (Fig. 3).

In group I, stainless steel interlocking nails and screws were used and in group II Titanium intramedullary intramedullary interlocking nails and screws were used with the help of accessory interlocking nail application instruments from the both IILN instrument box sets. The choice of implant and its size was determined on the basis of the age, weight of the dog and the diameter of the bone as measured from the pre-operative radiographs and type of fracture. In group I 5 mm stainless steel nail of 160

Table 3: Intra-operative observations (design of study)

Case no	Hematoma	Fibrous callus formation	IILN size	Screw size mm(no)		Ancillary fixation
				Proximal	Distal	
Group I stainless steel iiln						
1	Significant	Absent	5 mm, 160 mm	2 mm(2)	2 mm(3)	none
2	Significant	Present	7 mm, 140 mm	2.7 mm(2)	2.7 mm(3)	Fcw*
3	Non significant	Present	8 mm, 160 mm	3.5 mm(2)	3.5 mm(2)	none
4	Non significant	Absent	8 mm, 200 mm	3.5 mm(1)	3.5 mm(3)	none
5	Significant	Absent	8 mm, 200 mm	3.5 mm(2)	3.5 mm(2)	none
6	Significant	Absent	7 mm, 180 mm	3.5 mm(3)	3.5 mm(3)	none
Group II titanium iiln						
1	Non significant	Absent	6 mm, 180 mm	2.7 mm(2)	2.7 mm(2)	none
2	Significant	Absent	5 mm, 110 mm	2 mm(2)	2 mm(2)	none
3	Significant	Absent	6 mm, 140 mm	2.7 mm(2)	2.7 mm(2)	none
4	Significant	Absent	5 mm, 140 mm	2 mm(3)	2 mm(2)	none
5	Non significant	Present	5 mm, 160 mm	2 mm(1)	2 mm(2)	none
6	Significant	Absent	6 mm, 140 mm	2.7 mm(2)	2.7 mm(3)	none

*Fcw:full circlage wiring.



(A) Proximal and distal Aiming device; **(B)** Trocar; **(C)** Drill sleeve; **(D)** Drill sleeve; **(E)** Conical bolt; **(F)** Cannulated socket wrench; **(G)** Steinman pins trocar ended; **(H)** Long drill bits; **(I)** Extra long hexagonal screw drivers; **(J)** Extra long bone tap with T handle

Fig. 3: Interlocking nail and its accessories

mm length was used in a 19 kg (Mongrel) dog, 7 mm nail with 140 mm and 180 mm nail length was used in a 18 kg (Labrador retriever) and a 30 kg (German shepherd) dogs respectively. 8 mm, 160 mm length nail was used in a 42 kg body weight dog (Labrador retriever) and 200 mm length nail for a 36 kg (Saint Bernard) dog and a 20 kg (Mudhol hound) dog.

In group II, 5 mm, 160 mm length titanium nail was used in a 20 kg dog (Mongrel), another 5 mm, 140 mm length nail in a 11 kg dog (Pomeranian),a length contoured 5 mm, 110 mm nail was used in a 5 kg puppy (Golden retriever). 6 mm,140 mm nail was used in two 16 kg, and a 18 kg dogs respectively. All the three were mongrel dogs. The design of study is given in table 3.

The dogs with fracture of femur was positioned in lateral recumbency with the fractured limb up. The cranio-lateral border of thigh approach was used for exposure of fractured diaphysis region of femur bone to perform titanium intramedullary interlocking nailing (Piermattei and Johnson, 2014). Following the surgical exposure of the fracture site as described, the fracture fragments were aligned and reduced to restore the length and correct rotational orientation. (Dejardin *et al.,* 2012 and Dejardin *et al.,* 2020) A trocar ended Steinmann pin (of size 1-2 mm less than diameter of selected nail) was inserted into the medullary cavity through a retrograde manner from the proximal fragment and taken out through trochanteric fossa, followed by adequate reaming of proximal segment. It was then reinserted in to the distal fragment and reamed the medullary cavity of the distal fragment also. Following principles of indirect fracture reduction, the appropriate size intramedullary Interlocking nail was inserted in to the medullary cavity through the guidance tract made by the pin. The fracture was reduced and held in opposition with the help of bone-holding forceps applied proximal and distal to the fracture site. The aiming device was then connected to the nail and hammered untill the nail got completely reside inside the distal fracture fragment. With the nail in its final position, a drilling sleeve is applied to ensure the drill holes are accurately aligned to the holes in the nail. The drill bits of size 1.5 mm for 5.0 mm diameter nails, 2.0 mm for 6.0 mm and 7.0 mm nails and 2.5 mm for 8.0 mm nails were suitable for drilling holes across the bone. Cortical screws of diameter 2.0 mm, 2.7 mm and 3.5 mm were suitable after tapping with appropriate bone tap of size 2.0 mm, 2.7 mm and 3.5 mm respectively provided excellent results in the present study. At first the distal hole was bolted followed by other screwholes (Fig. 4).

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

The suture line was covered with a thin layer of sterile gauze bandage dipped in 5% povidone iodine solution, and covered with cotton padding and applied gauge bandage. 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

Fig. 4: Surgical procedure for repair of femoral fracture using aiming device for introduction of intramedullary interlocking nail

Table 4: Post-operative details of lameness grading

Case no	IILN material and diameter used	Preoperative lameness grading	Post operative lameness grading on					Complete weight bearing on
			1	15	30	60	90	
Group I								
1	Stainless steel, 5 mm, 160 mm	V	III	I	I	I	I	2
2	Stainless steel, 7 mm, 140 mm	V	II	I	I	I	I	2
3	Stainless steel, 8 mm, 160 mm	V	III	III	II	II	II	7
4	Stainless steel, 8 mm, 200 mm	V	V	IV	III	II	I	15
5	Stainless steel, 8 mm, 200 mm	V	III	II	II	II	II	8
6	Stainless steel, 7 mm, 180 mm	V	III	I	I	I	I	2
Mean		**5.0±0.0**	**3.16±1.2**	**2±2.3**	**1.6±6.2**	**1.5±2.3**	**1.3±3.1**	**6.0±2.1**
Group II								
1	Titanium, 6 mm, 180 mm	V	III	I	I	I	I	2
2	Titanium, 5 mm, 110 mm	V	II	I	I	I	I	2
3	Titanium, 6 mm,140 mm	V	III	II	I	I	I	3
4	Titanium, 5 mm, 140 mm	V	III	I	I	I	I	2
5	Titanium, 5 mm, 160 mm	V	III	II	II	II	II	10
6	Titanium, 6 mm, 140 mm	V	III	I	I	I	I	2
Mean		**5.0±0.0**	**2.8±3.3**	**1.3±3.2**	**1.16±2.6**	**1.16±2.6**	**1.16±2.6**	**3.5±2.5**

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.

body weight by intramuscular injection for 3 days post-operatively.

RESULTS AND DISCUSSION

Clinical evaluation for the presence of swelling, exudation and weight bearing in all the dogs. This suture line was also examined every day until the sutures were removed. The post- operative day on which the dog started bearing weight was recorded and graded (Table 4).

In group I, the mean lameness grading score on immediate post operative day, 15th , 30th, 60th, and 90th post operative days where 3.16±1.2, 2.1±1.2, 1.6±6.2,1.5±2.3, and 1.3±3.1 respectively. This shows gradual reduction in lameness grading score. In this group three dogs progressed to grade I lameness by the end of 30th postoperative day and two progressed to grade II by the end of 30th post-operative and grade I by 120th day and another dog to grade I on 90th post-operative day (Fig. 5). This finding was in agreement with the findings of (Duhautois, 2003 and Wheeler, 2004), and wherein they stated that grades of lameness for subsequent post-operative days gradually decreased in IILN technique of fracture repair. Also, Singh *et al.*, 2008 reported early weight bearing and quick rehabilitation, which could be attributed to adequate stability provided by the static intramedullary interlocking nailing.

In group II, the mean lameness grading score on immediate post operative day, 15th , 30th, 60th, and 90th post operative days are 2.8±3.3, 1.3±3.2, 1.16±2.6, 1.16±2.6 and 1.16±2.6 respectively. In this group four dogs progressed to grade I lameness by the end of 15th postoperative day and one dog progressed to grade I by the end of 30th post-operative day. Another dog progressed to grade II by end of 30th post operative day (Fig. 6). The findings were in accordance with (Randy *et al.,* 2004; Varshneya *et al.,* 2012). Also Jagan *et al.* (2021b) reported that early weight bearing and quick rehabilitation, which could be attributed to adequate stability provided by titanium IILN.

Lameness grading was superior in the group II of dogs but the implant stability was good in group I as the implant failure in this group was not seen. These were in accordance with (Disegi *et al.,* 2000; Pravalika *et al.,* 2021). In the group II dogs, earlier weight bearing and normal limb function were recorded with a mean of 3.5±2.5 days in compared to group I having a mean of 6.0±2.5 days, due to the fact

Fig. 5: Progressive weight bearing of right hind limb on different postoperative days in Group 1 case 1 dog

Fig. 6: Progressive weight bearing of right hind limb on different postoperative days in Group 2 case 1

that the titanium implants were lighter in weight compared to stainless steel (Farrell, 2016). Improved resistance to infection and improved healing compared to standard or stainless steel implant ideally suited for use in the small animal patients (Scotti *et al*.. 2007), titanium is lighter in weight, had superior fatigue and corrosive resistance, improved biocompatibility, lower young‘s modulus, lower shear strength and lower abrasion resistance and accurate and safe stabilization of diaphyseal fracture of long bones in dog with rapid return of limb activity as reported by (Mahar *et al.,* 2004; Jagan *et al.,* 2021a; Jagan and Dilip, 2021a and Jagan and Dilip, 2021b).

The radiographic assessment of both groups on regular intervels was interpreted in table 5. In Group I Immediate post-operative radiographic evaluation confirmed proper placement of stain less steel intramedullary interlocking nail with proximal and distal stainless steel screws, good apposition of the fractures fragments in all the six dogs. An additional cerclage wiring was applied in one dog along with stain less steel interlocking nail to immobilize the large wedge fracture fragments. The radiographs obtained on the 15th post-operative day revealed proper apposition and alignment of fracture fragments in all the six dogs. The radiographs obtained on the 30th post-operative day in all dogs showed evidence of callus formation. By 60th day, in five dogs, bridging callus formation, and in only one dog the fracture line disappeared showing clear restitution of cortico-medullary cavity. The radiographs obtained on the 90th postoperative day shows complete formation of bone with distinct cortico-medullary distinction at the fracture site in three dogs and in other three, they were still in the process of formation of the bone however, the dogs were bearing complete weight on the affected limb. In three dogs healing was fast, in other three dogs had slow healing without any complications (Fig. 7). The results of this group of dogs was in congruence with several workers (African *et al*., 2017 and Abhishek *et al.,* 2022) and screw bending as observed by (Suber *et al.,* 2002; Diaz *et al*., 2003 and Patwa *et al*., 2022).

In Group II, radiographic evaluation on immediate post-operative day confirmed proper placement in all dogs except in the fifth dog where the screw head was broken at the time of screw tightening. A very good apposition of the fractured fragments were present in all the six dogs. The radiographs obtained on the 15th post-operative day revealed proper apposition and alignment of fracture

Fig. 7: Progressive radiographic healing of femur fracture in case 2 of Group-I (immediate post operative day, 15th, 30th , 60th and 90th day)

Fig. 8: Progressive radiographic healing of femur fracture in case 4 of Group-II (immediate post operative day, 30th , 60th and 90th day)

fragments in all the six dogs. The radiographs obtained on the 30th post-operative day in all dogs showed evidence of callus formation. By 60th post-operative day the fracture line disappeared and the callus became radio-dense with clear establishment of cortico-medullary canal in 3 dogs. In other 3 dogs fracture gap and presence of callus indicated as under the process of healing. The callus pointing to the restitution of cortio-medullary continuity well appreciated on all the radiographs. Radiographs obtained on the 90th post-operative day revealed distinct cortico-medullary separation caused by remodeling; fracture line not visible in four out of six cases (Fig. 8). In one case fracture healing was slow and in another one nail bending caused instability and bone healing got compromised. The results of this group of dogs was in congruence with several workers (African *et al*., 2017) and screw bending and nail breakage as observed by (Horstman *et al.,* 2004; Wheeler *et al.* 2004), Jagan *et al*., 2021a and Patwa *et al.,* 2022).

In group I, with stainless steel intramedullary interlocking nailing technique, out of six dogs one dog with femur fracture showed stainless steel bolt bending on 90th postoperative day. However, the dogs had complete functional limb usage on 90th postoperative day. The owner had not showed much interest for removal of the implant. May be due to over activity of the animal,

Table 5: Details of Radiological scoring in the two groups of dogs

Case no.	Day 0			Day 30			Day 60			Day 90		
	Fracture alignment	**cccc***	**Radiological score**	**Fracture alignment**	**cccc***	**Radiological score**	**Fracture alignment**	**cccc***	**Radiological score**	**Fracture alignment**	**cccc***	**Radiological score**
Group -I stainless steel intramedullary interlocking group												
1	+	-	3	+	+++	1	+	+++	0	+	+++	0
2	+	-	3	+	+++	1	+	+++	0	+	+++	0
3	+	-	3	+	++	1	+	++	1	+	+++	1
4	+	-	3	+	++	1	+	++	1	+	+++	1
5	+	-	3	+	+++	1	+	+++	1	+	+++	0
6	+	-	3	+	+++	1	+	+++	1	+	+++	0
Group -II titanium intramedullary interlocking nail group												
1	+	-	3	+	+++	1	+	+++	0	+	+++	0
2	+	-	3	+	+++	1	+	+++	0	+	+++	0
3	+	-	3	+	+++	1	+	+++	0	+	+++	0
4	+	-	3	+	+++	1	+	+++	0	+	+++	0
5	+	-	3	+	+++	1	+	+++	1	+	+++	2
6	+	-	3	+	+++	1	+	+++	0	+	+++	0

Fracture alignment- '+' fracture fragments align in anatomical position, '-' fracture fragments not in anatomical position; *Callus formation and cortical continuity- '+++' Good callus, '++' Moderate callus, '+' Poor callus; Radiological score (Cook *et al.* 1999) : '0'- complete radiiogaphic healing, '1'-Appropriate progression towards healing, but not completely healed, '2'-Inappropriate progression towards healing, '3'- No evidence of healing, failure.

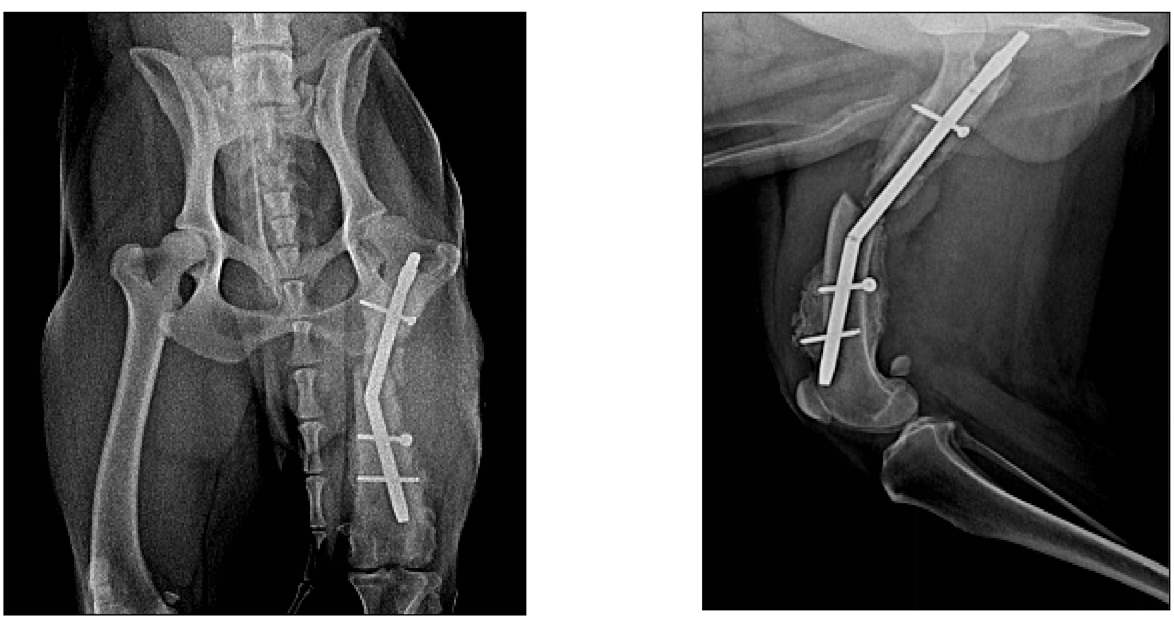


Fig. 9: Group II - Case 5, 90th Post-operative day skiagram showing bending of interlocking nail (cranio-caudal and medio-lateral view)

resulting in deviation in angulation of affected limb and inappropriate callus formation at the fracture site. These findings were in agreement with the findings of (Patel *et al.,* 2007 and Raghunath and Singh, 2008) where they listed post-operative complications like angulations of the bone, loosening of screws, and locking mistakes. (Singh *et al.,* 2007) reported that loosening of screw could be due to severe osteoporosis of bone, and (Budsberg *et al*., 2005) reported delayed union and superficial wound infection as other complications.

In group II, with titanium intramedullary interlocking nailing technique, out of six dogs, one dogs with femur fracture showed titanium nail bending on 90th postoperative day. However, the dog had complete functional limb usage on 60th post-operative day. The owner had not showed much interest for removal of the implant. Nail breakage caused an angulation in callus formation at the fracture site. These findings were in agreement with the findings of (Bhat *et al.*, 2006; Patel *et al.,* 2007 and Raghunath and Singh, 2008) where they listed post-operative complications like angulations of the bone, loosening of screws, and locking mistakes. The distal screw was bolted and fixed fairly but only two bolts were locked at the distal end this may not provided adequate stability for rigid fixation and in turn may caused implant failure before complete bone healing. Another cause may be due to the over physical activity of the animal.

In group I with stainless steel IILN, the first case had a screw bending happened on 90th postoperative day. However, the dogs had complete functional limb usage on 90th post-operative day. Radiological healing was completed by the 90th day. No other cases had any complications. In group II with titanium IILN, there was nail bending for one case on 90th post operative day (Fig. 9). Implant instability caused inappropriate healing and callus formation. This might be due to heavy weight and hyperactivity of the animal. These findings are in accordance with (Wheeler *et al.,* 2004; Patel *et al.,* 2007; Raghunath and Singh, 2008 and African *et al.,* 2017). Other complications namely stiffness of joint, nail dislodgement from distal segment of fractured bone, luxation of joint as reported by (Patwa *et al.,* 2022) was not encountered in the present study.

CONCLUSION

Based on the present study, it was concluded that intramedullary interlocking nail was successful in the treatment of femur fractures and offered remarkable improvement in the limb function with good fracture stability till the completion of the bone healing in eleven out of twelve dogs. Stainless steel and titanium intramedullary interlocking nails are a good treatment option for comminuted diaphyseal femur fractures. Titanium interlocking nail treated dogs had edge over stainless steel implants as the mean age of dogs to bear the complete weight and full function of the affected limb was earlier in this group. Also lameness grading was superior in group II dogs as it may be due to the fact that the titanium implants were lighter in weight, superior fatigue and corrosive resistance, improved biocompatibility, lower young‘s modulus, lower shear strength and lower abrasion resistance and accurate and safe stabilization of diaphyseal fracture of long bones in dog with rapid return of limb function.

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