



Evaluation of Titanium Elastic Nails for Femoral Fractures in Young Dogs: A Clinical Study

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ABSTRACT

Background: Femur fractures from multifactorial etiologies are a common occurrence in young and growing dogs. Various methods of internal fixation are available to repair young femur fractures but titanium elastic nails (TENs) are superior in stabilizing such fractures. Micromotion at the fracture site by these nails limits stress shielding and stimulates for early callus formation. TENs nails have been used in children but fewer studies are conducted in immature dogs in the recent years. The objective of this study was the clinical evaluation of TENs technique in femur fracture fixation among young dogs.

Methods: This study included 16 clinical cases of young (<2 months) dogs (12 male and 4 female) with mean $\pm$ SD age of 5.19 ± 2.83 month, body weight 7.46 ± 5.07 Kg injured since 2.93 ± 2.14 days and associated with vehicular accident, fall from height, hit injury with stick and unknown injury with femur fractures. TENs technique was applied in all the classes and postoperative clinical evaluation was done.

Result: All the cases resulted in satisfactory functional outcome based on radiographically visible early bridging callus with mean radiographic fracture healing score of 2.43 ± 0.18 , better fracture union (bone union score: 1.37 ± 0.24 and bone formation score: 2.25 ± 0.19), early weight bearing (standing: 2.43 ± 0.28 days, walking: 4.93 ± 0.39 days, pain perception score (1.62 ± 0.12) and ambulation with weight bearing score: 2.5 ± 0.12 (standing) and 3.00 ± 0.22 (walking), respectively on 15th postoperative day, in affected dogs with no major complications. Therefore, TENs technique provides an adequate repair of diaphyseal and supracondylar femur fractures in young dogs with better postoperative outcome.

Key words: Clinical outcome, Femur, Fracture, Stainless steel, Titanium elastic nails, Young dogs.

INTRODUCTION

Fractures cause suffering, pain and loss of function of affected limbs in animals (Vardhan *et al.*, 2017). Young and growing dogs are most frequently met with vehicular trauma causing long bone fractures (Harasen, 2003b; Elzomor *et al.*, 2014). Femoral fractures account for about 45% of all long bone fractures encountered in dogs (Piermattei *et al.* 2006). Stabilization of femoral fractures with open reduction and internal fixation is recommended as effective external coaptation methods are lacking for such fractures (Berg *et al.*, 1984). Caudal bowing of femur, larger medullary canal and eccentric loading of the bone while bearing weight are the major considerations for femoral fracture fixation in young dogs (Piermattei *et al.*, 2006). The main goal of fracture healing is the restoration of mechanical strength and the integrity of the fractured bone (Marsell and Einhorn, 2011). Elastic stable intramedullary nailing (ESIN) is a widely accepted method for surgical repair of diaphyseal fractures in children owing to its advantages like minimal invasion, early callus formation, avoidance of growth plate and early restoration of the bone continuity (Hunter, 2005) leading to rapid ambulation and the ability to maintain normal joint motion (Lascombes *et al.*, 2006). Minimally comminuted, short-oblique and transverse diaphyseal fractures are the best suited for ESIN technique (Flynn *et al.*, 2004). Titanium based implants have advantages like lower modulus of elasticity (high specific strength), better corrosive

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resistance, enhanced flexibility and better biocompatibility, inertness to tissue environment and high capability to join with bony tissues (Niinomi, 2003; Mahar *et al.*, 2004). Light weight of titanium implants allow micromotion at the fracture site, limit stress shielding and thereby stimulates rapid callus formation (Lv *et al.*, 2025). The present study was conducted with an objective of the clinical evaluation of femoral fracture fixation using Titanium Elastic Nails (TENs) in young dogs.

MATERIALS AND METHODS

The present study was duly approved by the Institutional Animal Ethics Committee (vide no. IAEC/01/23/KNPCVS/2024). It included 16 clinical cases of young (age less than 12 months) dogs: 12 male and 4 female with mean $\pm$ SD age of 5.19 $\pm$ 2.83 month (range 3.00-11.00 month), body weight 7.46 $\pm$ 5.07 Kg (range 3.2-20.1 Kg) since 2.93 $\pm$ 2.14 days (range 1-7 days) and associated with vehicular accident (n=10), fall from height (n=2), hit injury with stick (n=3) and unknown injury (n=1). Different breeds such as Non-descript (n=5), Doberman Pinscher (n=3), Labrador, German Shepherd, Pomeranian, Pit bull, Rottweiler, Indian Spitz, American Bully and Shih Tzu (1 each) were affected with right (n=10) or left (n=6) femur fractures. Signalment and the history was recorded and the cases with pelvic or spinal fractures and/or neurological deficits were excluded. Clinical examination of the cases evaluated general health and body condition score for general anesthesia. Two orthogonal radiographs (mediolateral and craniocaudal) of the fractured femur were obtained preoperatively as well as at different intervals during postoperative period. Hematological (total erythrocyte count, hemoglobin, packed cell volume, platelet count and total and differential leucocyte count) and serum biochemical (serum calcium, phosphorus and alkaline phosphatase activity) estimation was done preoperatively, intraoperatively and at different intervals postoperatively.

Selection of TENs was done based on measuring bone isthmus diameter (approx. 30-40% of isthmus diameter) using in-built caliper of computerized radiography. Preoperative antibiotic (inj. amoxicillin-sulbactam @ 12.5 mg/kg IM) and analgesic (inj. Meloxicam @ 0.2 mg/kg SC) were administered 30 minutes prior to the onset of surgical procedure. All the dogs were premedicated with inj. Atropine sulphate @ 0.04 mg/kg SC, inj. Butorphanol @ 0.2 mg/kg IM. Anesthetic induction was done with inj. Zolazepam-tiletamine @ 2.5 mg/kg IV

and was maintained with isoflurane. All the fractures were stabilized using TENs (size range=1.5 mm-3.0 mm) with both nails occupying approximately 60-75% of the medullary cavity. The standard surgical approach described previously by Johnson (2014) for femoral fractures was followed. The elastic nails were inserted (Fig 1) in a similar method as described by Sodhi *et al.* (2023).

Intraoperative observations such as hematoma formation at the fracture site and muscle adhesions were recorded as per Mathew (2019). Postoperatively, alternate day antiseptic dressing was done and modified Robert Jones bandaging was applied on the operated limb for 15 days. Inj. amoxicillin-sulbactam @ 12.5 mg/kg BID and inj. meloxicam @ 0.2 mg/kg OD was administered IM for 5 days and 3 days, respectively. Dog's movement was restricted for first ten postoperative days followed by progressive increase in passive range of motion exercises. Skin sutures were removed after 14 days of surgery.

Clinical and radiographic evaluations were performed at various time intervals (immediate postoperative and on 15th, 30th and 45th days). Radiographic evaluation of bone formation and its union at the fracture site was done as per the scoring system for bone formation (BFS) and bone union (BUS) described by Lane and Sandhu (1987). Pain perception score was assessed by palpation and manipulation of the affected limb and scoring was done according to the scoring system given by Cross *et al.* (1997) and fracture healing assessment (FHA) was done as per grading system by Pozzi *et al.* (2012). Weight bearing while standing and while walking was scored as per described by Sahu *et al.* (2017) while functional limb usage was evaluated by grading the degree of lameness according to the classification system developed by Fox *et al.* (1995). The implant was removed aseptically from the distal end after the clinical union of fracture, under general anesthesia. Data analysis was done using one-way ANOVA and results were considered statistically significant when $P < 0.05$.

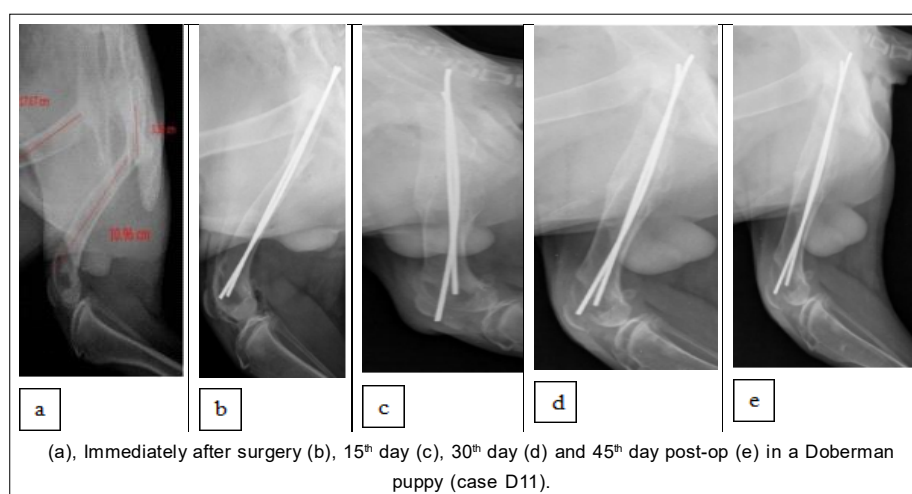


Fig 1: Sequential radiographic images depicting proximal-third diaphyseal femur fracture healing from preoperative.

RESULTS AND DISCUSSION

This study included young dogs (less than 12 months old) suffering from femoral fractures with higher incidence in males (75%) and right femur (68.75% cases) was the most commonly affected. Vehicular trauma was the most common etiology (62.50% cases) followed by hit injury from stick (15.78%), fall from height (12.5%) and one case suffered from unknown etiology. Most of the cases weighed between 3-10 Kg (75% cases). Mean $\pm$ S.E. duration of injury was 2.93 $\pm$ 0.53 days. Preoperative swelling (mild in 37.50%, severe in 31.25% and moderate in 18.75% cases) and crepitus (50% cases) were observed.

Distal one-third femoral fractures were the most common (43.75% cases) followed by mid-diaphyseal (31.25%), supracondylar (Salter-Harris type 1: 18.75%) and proximal one-third (6.25%) fractures. Transverse (68.75% cases) and oblique (31.25%) type of fractures were observed with overriding (62.5%) fracture fragments (Gupta *et al.*, 2023).

Two similar sized TENs inserted symmetrically in double C-shaped configuration created six-point fixation and prevented mal-alignment by providing equal opposing forces (Mahar *et al.*, 2004). However, in one case, a single 3.5 mm TENs was used in S-shaped configuration. Harasen (2003) reported that even if a single nail is dynamically loaded, the stability of the construct will not be disturbed. Intraoperative, hematoma at the fracture site (mild in 43.75%, moderate in 25% and severe in 18.75% cases) and muscle adhesions (mild and moderate each in 37.50% cases and severe in 12.50%) were recorded. Fracture reduction was difficult in (18.75% cases) which could be because of delayed presentation, callus formation and quadriceps contracture (Gill *et al.* 2018b). The 3-point contact of the nail was accurately achieved only in 31.25% cases which could be because of inserting unbent nails into the medullary cavity (Gupta *et al.*, 2023). Radiographic callus formation was evident on the 15th postoperative day with mean bone formation score (BFS): 2.25 $\pm$ 0.19 and mean bone union score (BUS): 1.37 $\pm$ 0.24 (Table 1). The callus formation was enormous and rapid and micro-motion allowed by titanium nails at the fracture site could be attributed to limit stress-shielding and thus stimulate rapid callus formation (Tiwari *et al.*, 2024; Lv *et al.*, 2025). TENs removal was done after desired functional limb outcome was achieved and a satisfactory radiographic bone remodeling was evident after TENs removal (Fig 2).

Pain perception score (PPS) showed a significant decrease from immediate postoperative (0 day) till 30th postoperative day. Immediate postoperative mean PPS (3.68 $\pm$ 0.11) reduced till 15th day (1.62 $\pm$ 0.12) and 1.00 $\pm$ 0.00 on 30th postoperative day (Table 1). Mean radiographic fracture healing (Fig 1-4) score improved significantly from 5.00 $\pm$ 0.00 (0th day) to 2.43 $\pm$ 0.18 (15th day), 1.56 $\pm$ 0.18 (30th day) and finally to 1.00 $\pm$ 0.00 on the 45th post-op day (Table 1). Additionally, bone formation score (BFS) and bone union scores (BUS) were 0.00 $\pm$ 0.00 (0th day) and both increased significantly to 3.75 $\pm$ 0.11 and 3.62 $\pm$ 0.20, respectively through 45th postoperative day (Table 1).

Majority of the cases healed without any complications. However, distal migration of nails in three (18.75%), self-mutilation in one (12.5%) and quadriceps contracture in one (6.25%) case (Fig 5) were recorded during postoperative period (Cebeci and Karsli, 2021; Sodhi *et al.* 2024). A significant increase in weight bearing scores was observed from preoperative to the subsequent follow-ups (Fig 6). Mean preoperative weight bearing score on standing (WBS-S) and while walking (WBS-W) was 0.00 $\pm$ 0.00 which gradually improved to 2.5 $\pm$ 0.12 and 3.00 $\pm$ 0.22 on 15th postoperative day, respectively and further to 3.00 $\pm$ 0.00 and 4.00 $\pm$ 0.00 on the 30th postoperative day, respectively (Table 1). A satisfactory early weight bearing (mean $\pm$ S.E.) was observed on an average of 2.43 $\pm$ 0.28 days (standing) and 4.93 $\pm$ 0.39 days (walking) postoperatively. Deshpande *et al.* (2023) reported weight bearing of average 3.00 $\pm$ 1.09 days in dogs with long bone fracture treated with locking compression plates along with silver fluorophosphate graft strips as osteoinducers.

Significant decrease in rectal temperature, heart rate and respiratory rate was observed from preoperative period to immediate postop period which further increased significantly to subsequent follow-ups (Pereira *et al.*, 2019; Koli *et al.*, 2021). A significant increase (total erythrocyte count, lymphocyte, monocyte, eosinophil and platelet) and a significant decline (total leucocyte count and neutrophils) was observed from preoperative till 45 postoperative days. No significant change was observed in hemoglobin and packed cell volume. Elevated preoperative alkaline phosphatase values decreased significantly till final follow up (Patil *et al.*, 2017). A significant increase in serum calcium and significant decline in serum phosphorus levels was observed from preoperative to 45th postoperative days (Hegde *et al.*, 2007; Reddy *et al.*, 2020).

Table 1: Mean $\pm$ S.E. values of postoperative variables in dogs at different intervals.

Parameters	0 d	15 d	30 d	45 d
Weight bearing score on standing (WBS-S)	0.00 $\pm$ 0.00 ^d	2.50 $\pm$ 0.12 ^c	3.00 $\pm$ 0.00 ^b	3.00 $\pm$ 0.00 ^a
Weight bearing score on walking (WBS-W)	0.00 $\pm$ 0.00 ^d	3.00 $\pm$ 0.22 ^c	4.00 $\pm$ 0.00 ^b	4.00 $\pm$ 0.00 ^a
Pain-perception score (PPS)	3.68 $\pm$ 0.11 ^a	1.62 $\pm$ 0.12 ^b	1.00 $\pm$ 0.01 ^c	1.00 $\pm$ 0.01 ^c
Fracture healing assessment (FHA)	5.00 $\pm$ 0.00 ^a	2.43 $\pm$ 0.18 ^b	1.56 $\pm$ 0.18 ^c	1.00 $\pm$ 0.00 ^d
Bone formation score (BFS)	0.00 $\pm$ 0.00 ^d	2.25 $\pm$ 0.19 ^c	2.81 $\pm$ 0.10 ^b	3.75 $\pm$ 0.11 ^a
Bone union score (BUS)	0.00 $\pm$ 0.00 ^d	1.37 $\pm$ 0.24 ^c	3.37 $\pm$ 0.24 ^b	3.62 $\pm$ 0.20 ^a

Means bearing different superscripts (a-d) within a row differ significantly at $p < 0.05$.

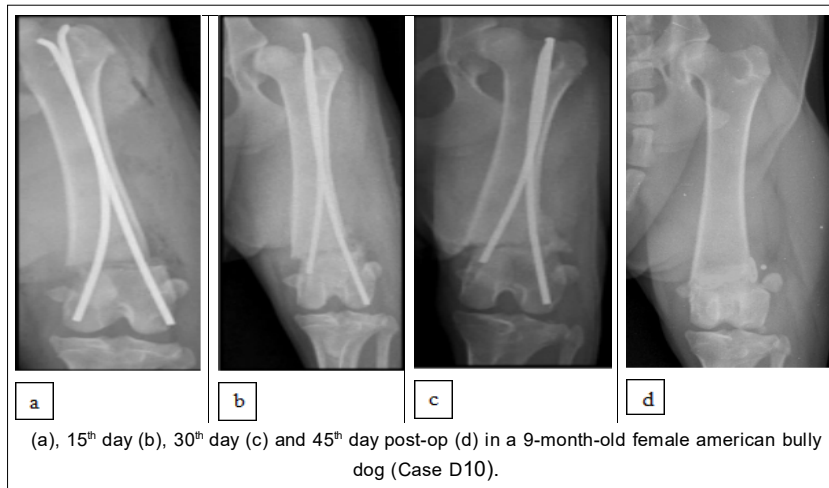


Fig 2: Sequential radiographic images depicting Supracondylar (Salter-harris type 1) fracture healing from immediately after surgery.

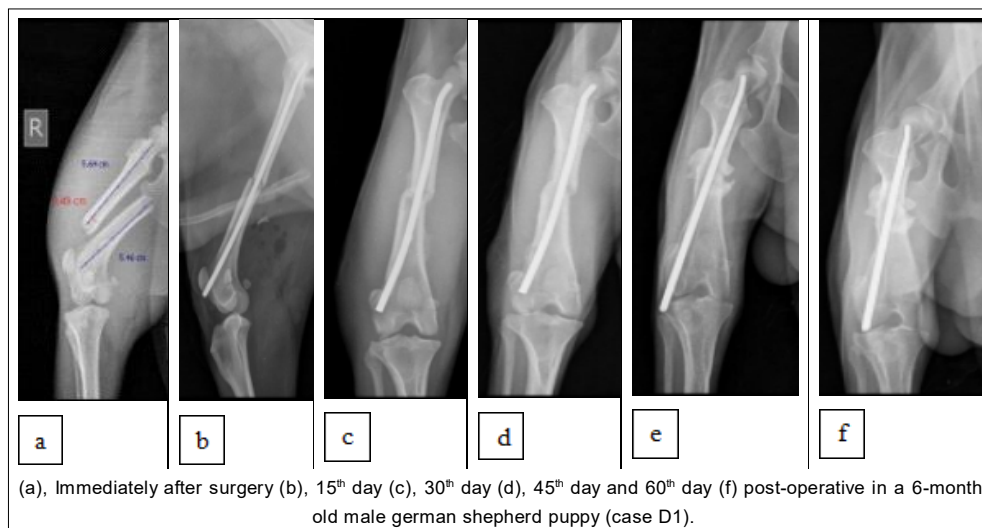


Fig 3: Sequential radiographic images depicting middle-third diaphyseal femur fracture healing from preoperative.

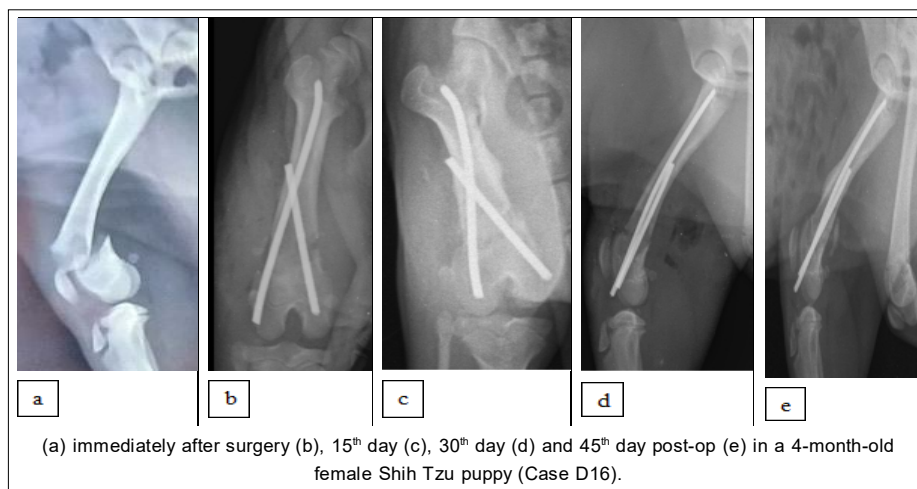


Fig 4: Sequential radiographic images depicting supracondylar fracture healing from preoperative.

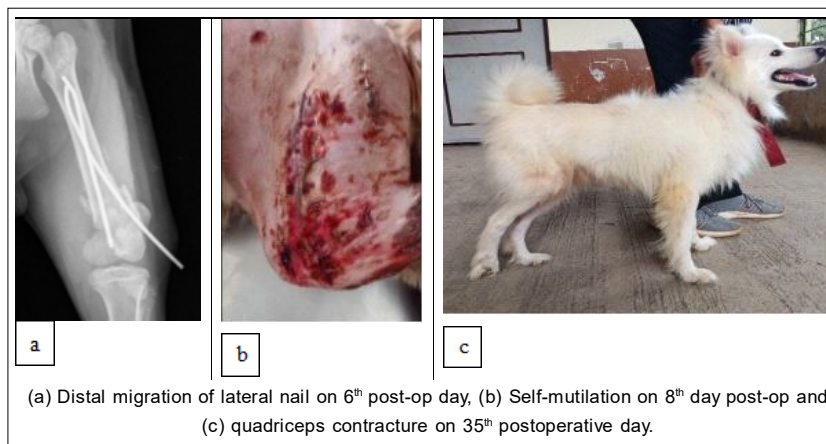


Fig 5: Complications encountered during postoperative period.

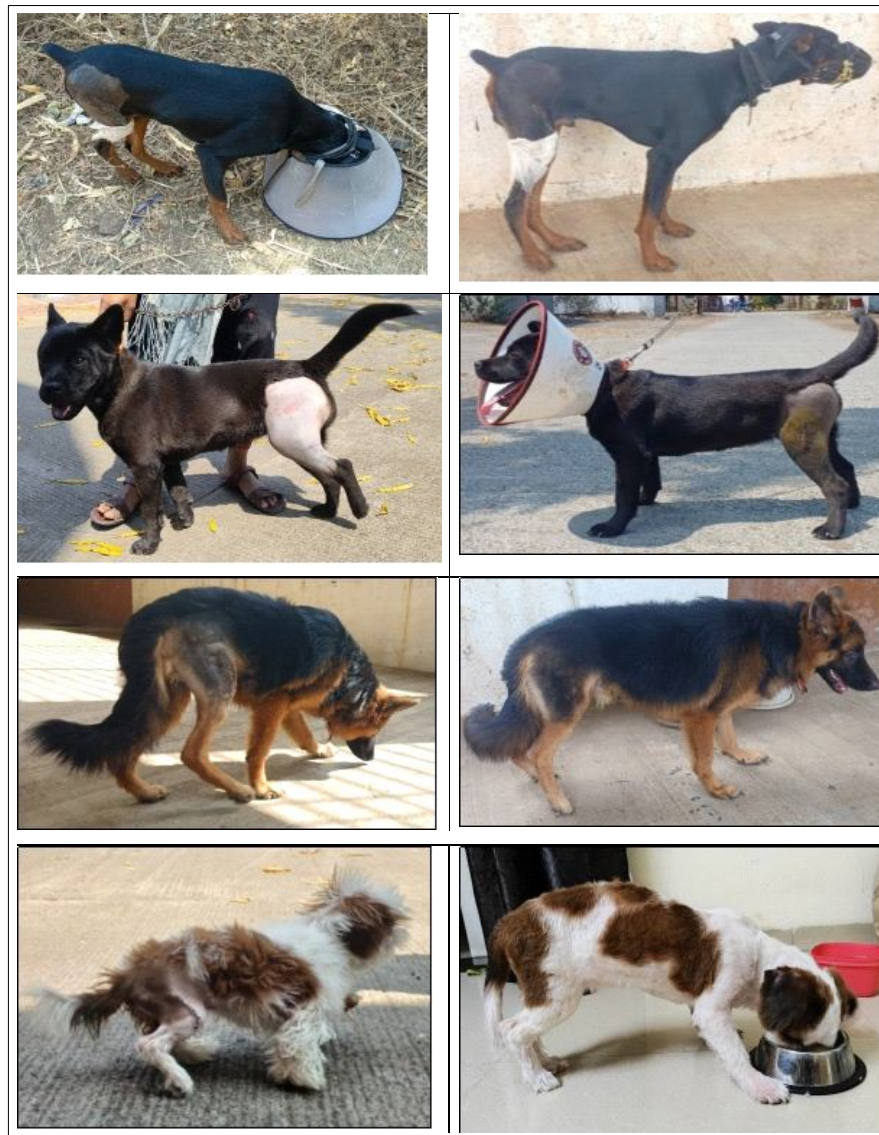


Fig 6: Functional outcome-early postoperative weight bearing and ambulation on 3rd and 15th postoperative days among the cases corresponding to radiographs depicted in Fig 1 to Fig 4.

Sodhi *et al.* (2023); Gupta *et al.* (2023) and Tiwari *et al.* (2024) reported adequate stability and satisfactory outcomes in young dogs treated using the TENS technique, which corroborates the findings of the present study, but contrasts with the observations of Wall *et al.* (2008). Based on the clinical outcomes of 16 femoral fracture cases, it can be concluded that TENS enhances bone healing by providing sufficient stability and facilitating early ambulation without major complications.

CONCLUSION

Based on the findings of this study it can be concluded that the titanium elastic nailing (TENS) technique is a reliable and effective method for stabilizing femur fractures in young dogs. It promotes early callus formation, rapid weight-bearing, and satisfactory bone healing with minimal complications. The positive clinical and radiographic outcomes highlight TENS as a superior fixation method for immature canine femur fractures. Overall, TENS offers a promising approach for achieving functional recovery and stable fracture union in young dogs.

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Disclaimers

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Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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