



## A comparative study between stainless steel and titanium elastic nails in the surgical management of canine juvenile femoral fractures

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### ABSTRACT

This prospective clinical study included 16 dogs presented with femur fracture, with no dog more than 12 months of age and were randomly divided into two groups; Group 1 (n=9) treated with stainless steel elastic nails and Group 2 (n=7) treated with titanium elastic nails. Signalment (breed, age, gender, body weight) and history (aetiology, duration of fracture and limb involved) were recorded on the presentation of patient, which was followed by clinical and radiographic examination to record fracture characteristics (site and type of fracture). Post-operatively, functional outcome was assessed on the basis of weight bearing status which improved in both the groups without significant difference. However, a few complications were observed in both the groups which included distal migration of implant (n=3) and osteoarthritis and quadriceps contracture (n=1) in Group 1 and distal migration of implant (n=2) and delayed union (n=1) in Group 2. One case in Group 1 and two cases in Group 2 needed implant removal. The functional outcome and rate of complication at the end of the study, however, was found to be comparable in both the groups and hence, it was concluded that both the implants provide comparable stability for the repair of femoral fractures in growing dogs.

**Keywords:** Dog, Dynamic intramedullary cross pinning, Femur fracture, Flexible nails, Functional outcome, Stainless steel elastic nails, Titanium elastic nails

Femoral fractures in dogs occur most frequently, accounting for about 45% of all long bone fractures (Piermattei *et al.* 2006). Lack of effective external coaptation methods for fractures above the stifle joint and inability to reduce caudally displaced fracture by external manipulation (Berg *et al.* 1984), stabilization of femoral fractures by open surgical reduction and internal fixation are recommended. The larger medullary canal, the caudal bow of the distal femur, and eccentric loading of the bone during weight bearing (Piermattei *et al.* 2006) are the major concerns for the internal stabilization of the femoral fractures in young dogs. Also, the distal femoral physis should be preserved during stabilization as it accounts for 70% of the total femoral bone growth and 40% of the overall limb growth (Harasen 2001). Hence, an adequately rigid fracture fixation technique that offers preservation of the distal growth plate is preferred.

Dynamic intramedullary cross pinning significantly prevents bending, horizontal shear, and rotational forces, but this implant provides less stability than cross pinning which is a rigid fixation technique (Sukhiani and

Holmberg 1997). However, flexible nails used in dynamic intramedullary cross pinning recoil when stressed and do not experience catastrophic failure as cross pins, hence preventing severe hardware failure (Battle *et al.* 2006).

Titanium and stainless steel are commonly used materials for flexible (elastic) pin implants with Titanium having certain advantages over stainless steel nails, such that it has higher corrosion resistance, higher flexibility, and better biocompatibility. The stainless-steel nails on the other hand are stiffer but more cost-effective than titanium (Hayes and Richards 2010, Goyal *et al.* 2014). A recent study reported encouraging results with the use of titanium elastic nails in comparison to single-end threaded pin for the stabilization of supracondylar and distal diaphyseal femoral fracture in young dogs (Sodhi *et al.* 2021a). However, there is a paucity of published literature on the comparison of stainless steel and titanium elastic nails, placed in a dynamic cross intramedullary fashion, to stabilize femoral fractures in growing dogs.

### MATERIALS AND METHODS

This prospective study on 16 clinical cases of growing dogs suffering femur fractures was duly approved by Institutional Animal Ethics Committee. The study was carried out during the year 2021-22 at the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana,

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Punjab, India with latitude and longitude coordinates of 30°89'4.67" N and 75°80'5.47" E. At initial presentation, signalment, and history were recorded. Clinical examination evaluated systemic soundness of the patient for general anaesthesia. Two orthogonal (anteroposterior and mediolateral) radiographs of the fractured bone were obtained pre-operatively (to determine narrowest medullary cavity diameter and to describe location and type of fracture) and postoperatively at various intervals.

Haematology (haemoglobin, total and differential leukocyte count, total erythrocyte count, packed cell volume, and platelet count) and serum biochemistry parameters (creatinine kinase, alkaline phosphatase, calcium, and phosphorus) were determined pre and postoperatively. Goniometry of the stifle joint and thigh girth measurements of affected and contralateral normal limb were measured (Supplementary Fig. 1) pre and postoperatively to assess Passive Range of Motion (PROM) and muscle atrophy, respectively.

All the fractures were stabilized by progressive dynamic intramedullary cross pinning using stainless-steel (SEENs; Group 1, n=9) and titanium elastic nails (TENs; Group 2, n=7) sized 1.5 mm, 2 mm, and 2.5 mm under general anaesthesia. Each nail was chosen to occupy 30-40% of the narrowest medullary canal (60-75% with both nails), as measured by in-built software in a computerized radiography system. The elastic nail had a customized bent tip and the other end was also bent to the same extent and direction using an orthopaedic plier before insertion, to know the orientation of the bent tip of the elastic nail inside the medullary cavity during insertion. A standard surgical approach described previously by Johnson (2013) for femoral fractures was followed. The elastic nails were placed similar to the method described by Sodhi *et al.* (2021a). The operated limb was supported with modified Robert Jones Bandaging for 2 weeks and were prescribed with cefotaxime @ 20 mg/Kg and meloxicam @ 0.2 mg/Kg, intramuscularly, for 5 and 3 days, respectively.

Damage to the surrounding muscles and soft tissue, callus formation, ease of reduction, type of implant used, number of attempts required to place each elastic nail into the medullary cavity, nibbling of fragments, damage caused to bone due to fixation, duration of surgical procedure, type of ancillary fixation used, if any, were recorded intra-operatively.

On immediate post-operative radiograph, fracture fragments alignment and reduction was graded as excellent, good and satisfactory, where excellent grade was given to complete anatomical reduction, very good and satisfactory was given to near perfect and non-perfect reduction respectively on immediate post-operative radiographs. Symmetry of implant i.e. accurate 3 point contact of implant with bone was also assessed.

All dogs were followed to record weight bearing on the basis of lameness score (Gill *et al.* 2018a) and to evaluate functional outcome. The objective parameters pertaining to signalment, clinical, haemato-biochemistry, radiography

in these two groups were subjected to student's t-test to determine significant difference at  $p < 0.05$  and  $p < 0.01$  between the two groups. Other parameters were compared on percent basis between the groups. The mean $\pm$ SD was calculated on all the objective parameters.

## RESULTS AND DISCUSSION

This study included young dogs (not more than one year of age) suffering from femoral fractures with higher incidence in males (62.5%) as compared to females (37.5%) and right femur more commonly affected (56.25% cases). Three dogs also suffered from associated orthopaedic ailments and were recumbent on presentation, but all these dogs had an uneventful recovery. Fall from height was the most common cause of injury (50%), followed by automobile trauma (43.75%). Entrapment of hind limb was also a reported cause in one case.

Maximum number of cases in Group 1 (55.55%) weighed between 10-15 kg and < 10 kg in Group 2 (57.14%). Cases which reported distal migration of implant in both the groups also corresponded to the above mentioned respective ranges of body weight, which was a peculiar finding as it dismissed the results from previously reported literature that states implant migration to be more common in heavier patients (Sagan *et al.* 2010).

Mean age of fracture was  $5.78 \pm 2.73$  days and  $5.29 \pm 4.46$  days in Group 1 and 2; however fractures more than ten days old were difficult to reduce and one case also reported delayed union in Group 2, but that dog had an uneventful recovery. 25% of all the cases presented had slightly pale mucus membrane with less haemoglobin content (7.5-9.5 g/dl) than normal physiological values, which could be attributed to their very young age (2-5 months old) as reported by Khan *et al.* (2011). No significant alterations were found in other vital parameters like heart rate, respiratory rate and temperature in both the groups.

Preoperative elevation and subsequent reduction during follow up in AKP values along with slightly elevated serum calcium, phosphorus in present study indicated proliferation of osteogenic cells and hence, osteosynthesis in both the groups (Patil *et al.* 2017). Delayed cases (> 7 days) operated in both the groups showed non-significant elevation of serum AKP and P and posed difficulty in reduction of fracture fragments intra-operatively due to callus formation and muscle contracture (Gill *et al.* 2018b). CK values at first follow up were significantly higher ( $p < 0.05$ ) in group 1, indicating higher muscle damage as compared to group 2 which could be attributed to higher biocompatibility of TENs (Hayes and Richards 2010).

Two elastic nails of same size were used for fracture fixation in each case to provide equal opposing forces and hence, preventing mal-alignment (Vishwanath and Satheesh 2017). Two cases each in either group required ancillary fixation with cerclage wires. Despite best efforts, 33.33% cases in Group 1 and 28.57% cases in Group 2 had < 50% coverage of medullary cavity after placement of both the

nails, which could be attributed to inadequacy in available implant sizes for wider medullary cavity of large breed dogs in this study. Functional outcome of all these cases was satisfactory and no major complication was encountered except in one case from Group 2 requiring implant removal due to distal migration. Similar observations were made by Saseendar *et al.* (2010) in paediatric femoral fracture repair using TENS.

Fracture fragments were very difficult to reduce in 33.33% and 28.57% cases in Group 1 and Group 2, respectively and it could be because of delay in presentation, leading to quadriceps muscle contracture, callus formation (Gill *et al.* 2018b), and excessive over-riding or due to more displacement of fracture fragments.

Placement of nail from lateral condyle was found to be easier in both the groups. This could be attributed to the fact that in majority of the cases, lateral nail was placed first, which might have caused difficulty in placement of second nail (Saseendar *et al.* 2010). The average duration of surgery was more in Group 1 ( $83.86 \pm 16.61$  min.) as compared to Group 2 ( $80.55 \pm 14.67$  min.). In one study by Wall *et al.* (2008), no difference in insertion time was found between TENs and SSSENs.

Distal one-third fracture of femur (43.75%) was the most common fracture site among the cases included in the present study, followed by supracondylar (37.5%) and mid shaft (18.75%) fractures. Amongst supracondylar fractures, Salter-Harris type 2 fractures (66.67%) outnumbered type 1 (33.33%). Transverse, spiral, oblique and comminuted fractures were also reported. Caudo-medial displacement of fracture was observed in majority of cases (43.5%), but caudal, cranial, cranio-lateral, caudo-lateral fracture displacements were also reported. One case had non-displaced fracture fragments (Berg *et al.* 1984).

On evaluation of immediate post-operative radiographs, fracture reduction was excellent in 25% cases, very good

and satisfactory in 37.5% cases each. Accurate 3-point contact of the nail with the cortex of bone was achieved only in 22.22% cases in Group 1 and 14.29% cases in group 2, despite best efforts. This could be due to the fact that the modified technique was used by inserting unbent nails into the medullary cavity which were bent after being advanced to desired extent inside the medullary canal using orthopaedic plier (Sodhi *et al.* 2021a and Sodhi *et al.* 2021b). Harasen (2001) reported that even if we are unable to achieve an accurate 3-point contact and only one nail is dynamically loaded, stability of the construct will not be hindered and hence, nails should not be redirected.

On first follow-up, one case from Group 2 suffered distal migration of medially placed nail on 6<sup>th</sup> post-operative day, which penetrated out of the medullary cavity and had to be removed. Radiographically, implant was stable in all (Figs1 and 2) except 3 cases in Group 1 and 2 cases in Group 2 because of distal migration of elastic nails, but fracture line was visible in all the cases and hence, implant was not removed in any (Supplementary Fig. 2 and Supplementary Fig. 3). On subsequent follow up, one of these cases from Group 1 (presented 11 months post-surgery), despite weight bearing on affected limb, developed quadriceps contracture, osteoarthritis of stifle joint and non-healing wound on medial side of condyle (Supplementary Fig. 4) due to continuous impingement of soft tissues and skin by migrated implant. One case from Group 2 developed non-weight bearing lameness on operated limb due to distal implant migration (35 days post-operatively) (Supplementary Fig. 3). Implant was removed from these two dogs with difficulty. The complications of distal migration of elastic nails are supported by findings of Bardet (1987), Wall *et al.* (2008) and Sodhi *et al.* (2021a). Inadequate nail size to medullary cavity ratio (<50%), neutral placement of nails, lack of anatomical reduction could be associated with distal migration of nails in these

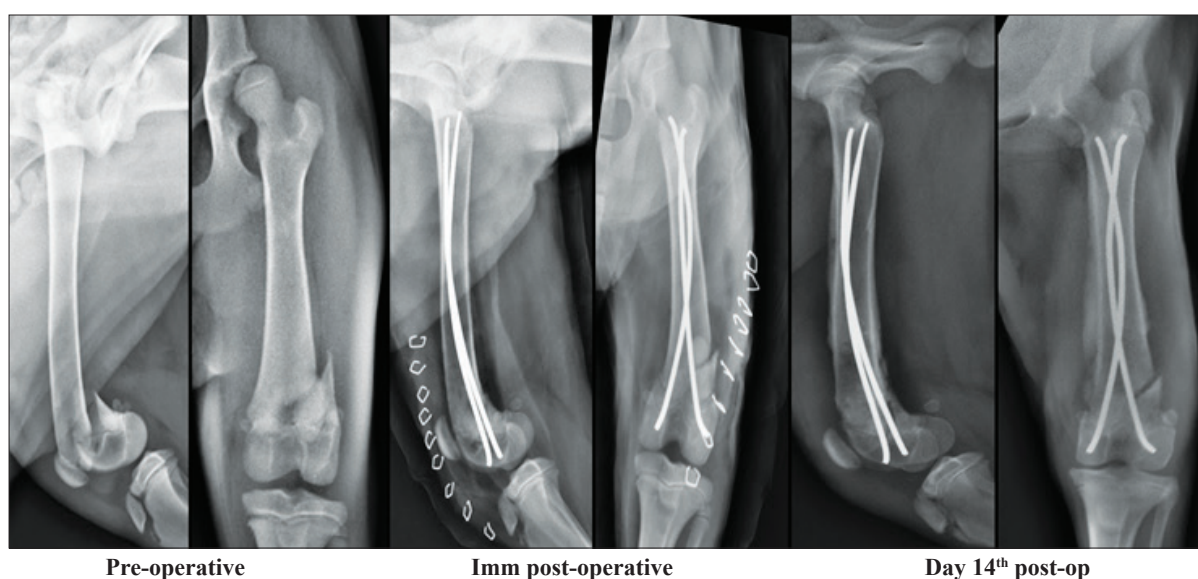


Fig. 1. Serial photographs and radiographs of a 4 months old Labrador pup weighing 11.2 Kg with 5 days old femur fracture repaired with SSSENs (Group 1) and showing excellent outcome.

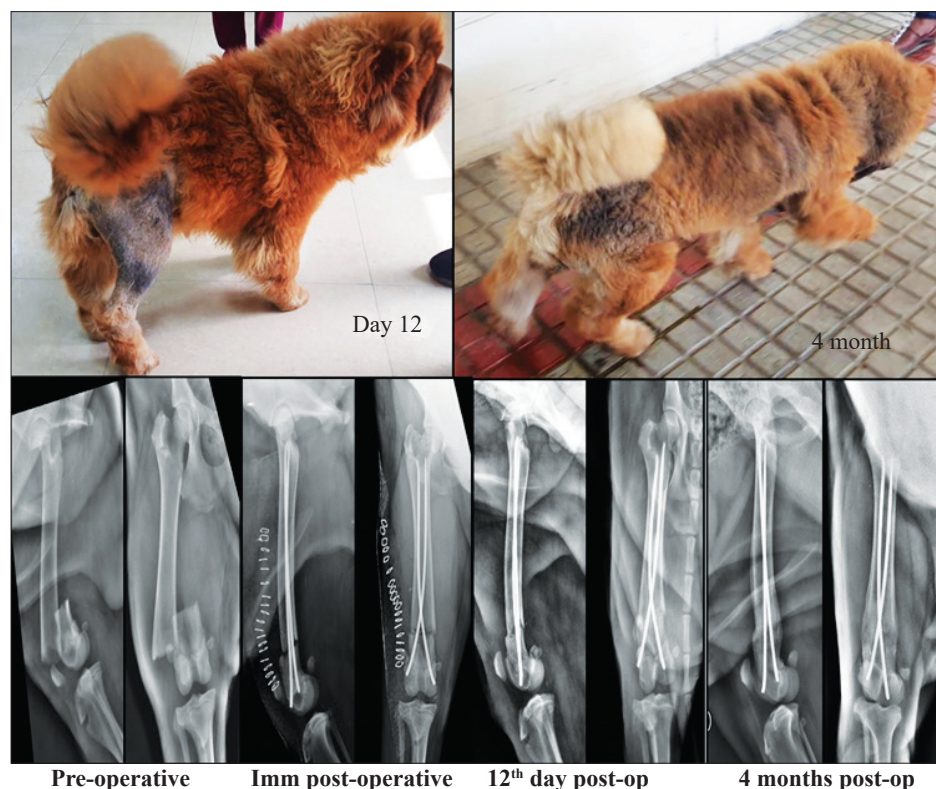


Fig. 2. Serial photographs and radiographs of a 7 months old Chow Chow pup weighing 23 kg with one day old femur fracture repaired with TENs (Group 2) and showing excellent outcome.

cases; however, the exact reason for migration could not be ascertained as other cases with improper anatomical reduction or lack of 3-point contact of nail have shown excellent recovery.

One case in Group 2 with asymptomatic distal nail migration on first follow up showed delayed union radiographically and crepitus in stifle joint when presented at 3 months post-operatively; however, that dog had excellent recovery.

All the cases of Group 1 and 85.71% cases in Group 2 had preoperative lameness score of 0 on fractured limb while standing or walking. One case in Group 2 had lameness score of 1 on standing and walking, preoperatively. Lameness score improved for all the cases during subsequent follow up except one case in Group 2 for which lameness score was 0 on standing and while walking due to distal migration of the implant, which improved after implant removal. Weight bearing status were comparable in both the groups (Goyal *et al.* 2014) despite TENs being biomechanically superior and more biocompatible as compared to SSENs (Hayes and Richard 2011).

Rehabilitation of operated limb for femur fracture was evaluated via PROM of stifle joint measured with universal goniometer (Dyke 2014) and facilitated by measuring thigh girth of both operated and contralateral limb to assess muscle atrophy (Jarvela *et al.* 2002). PROM improved in both the groups during subsequent follow up when compared to pre-operative values of affected limb, however, these values are significantly less than contralateral normal in Group 2.

Positive correlation between improving ROM and increasing thigh girth and hence muscle mass of operated limb during subsequent follow ups was seen only in Group 2 indicating muscle atrophy in Group 1. Improvement in range of motion in Group 1 could also be because of lower flexion angles in atrophied limb as compared to healthy limb with heavier muscle interfering with the flexion (Sabanci and Ocal 2016). Despite the differences in goniometric and thigh girth measurements in both the groups, there was no significant difference in the ultimate functional outcome of both the groups. Majority of the cases in both the groups healed without any complication. Complications observed in the present study i.e. quadriceps contracture, delayed union, osteoarthritis and distal migration of nails are very well documented in the literature for treatment of paediatric long bone fracture by elastic nails (Cebeci and Karsli 2021), but other possible complications like malalignment of fracture or angular deformity, osteomyelitis, superficial infection and non-union (Wall *et al.* 2008) were not reported in this study (Vishwanath and Satheesh 2017).

Overall functional outcome and complications, in this study, were comparable in both the groups. Hayes and Richard (2011) and Goyal *et al.* (2014) also supported the similar result in their respective studies, contrary to superiority of TENs reported in literature for femoral fracture stabilization in young patients (Battle *et al.* 2006). A study by Wall *et al.* (2008) reported higher complications with TENs as compared to SSENs and hence, recommended

SSEns over TENs.

Sixteen clinical cases of femoral fractures in growing dogs were repaired using Stainless-steel and Titanium elastic nails placed in a Dynamic Intramedullary Cross fashion. Functional outcome and complication rate were found to be comparable in both the groups. In conclusion, the Stainless steel and Titanium elastic nails provide comparable and adequate stability for the repair of femoral fractures in growing dogs that ensured satisfactory functional outcome; however, further studies on the large sample size are recommended.

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