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Titanium Elastic Nails for Distal Radius-ulna Fractures in Young Dogs

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ABSTRACT

Background: Radius-ulna is the most frequently fractured bone of the pectoral limb in dogs with high predisposition to distal fractures. The smaller size of the distal fragment and open physis restrict the use of rigid fracture fixation techniques in distal fractures of growing dogs. Titanium elastic nails (TENs) are recommended in medical practice to stabilize long bone fractures in children. There is paucity of literature on TENs for the repair of radius-ulna fractures in dogs.

Methods: This clinical study enrolled 10 dogs (7 grey hound and one each of Crossbred, Pomerenarian and Siberian Husky) suffering from distal radius-ulna (6 transverse and 4 short oblique) fractures since a mean ± SD duration of 3.40±4.5 days. The mean ± SD age and body weight of the dogs was 12.60±6.45 months and 14.09±6.41 Kg, respectively. All except one fracture was stabilized with two TENs inserted into the medullary canal of radial bone in a normograde manner from distal to proximal end using open cranio-lateral surgical approach.

Result: Majority fractures achieved satisfactory reduction (n=8), radiographically. Weight bearing scores on walking increased gradually from day 12 (1.62 ± 1.51) to 45th (2.57±1.51), day 60th (3.75±0.5) and day 90 (4.0±0). Five dogs had uneventful recovery whereas remaining had major (n=2) or minor (n=3) complications. The length of the operated bone was non-significantly lesser as compared to contralateral healthy bone on day 60. Goniometric assessment of carpal joint of operated limb showed restricted range of motion on day 12 that improved to the near normal as contralateral healthy limb on day 60. Long-term results showed full (9) and acceptable (1) functional outcome. In conclusions, the TENs technique is simple and less invasive alternative fixation technique for distal radius-ulna fractures in young and light weighing dogs. As per authors, this is the first report on the use of TENs for the management of radius-ulna fracture in dogs.

Key words: Canine, Goniometry, Intramedullary, Orthopedic surgery, Radiography, Radius-ulna fracture, Titanium elastic nails.

INTRODUCTION

In pectoral limb, fractures of radius-ulna are encountered most commonly in dogs with high predisposition to distal fractures (Simon *et al.,* 2011). Bone plates and screws are used as the primary fixation method for distal radial fractures in mature dogs (Welch *et al.,* 1997). The smaller distal fragment and open physis restrict the use of rigid fracture fixation techniques such as bone plates in distal fractures of growing dogs. Intramedullary pinning is usually not recommended due to impingement on joint surfaces, limited medullary canal diameter and cranial bowing of the radial bone (Schrader, 1991). External coaptation alone is too inadequate to achieve fracture stability of forearm fractures. As compared to adult, immature bones have thinner cortices, a larger medullary cavity and lower strength and stiffness (Dejardin and Cabassu 2008); thus, implant failure due to screw pull-out is very common in immature canine bone. Besides, bone plating requires more dissection of soft tissues and periosteum along the fractured bone, which contradicts the concepts of biological osteosynthesis. Furthermore, the removal of bone plates after fracture union demands a major surgical intervention under general anaesthesia, which is associated with increased surgical costs, anaesthesia, postoperative treatment and surgical wound care (Kumar *et al.,* 2020).

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In comparison to static fracture fixation, controlled micro-movements at the site of fracture (dynamic fracture fixation) have demonstrated to facilitate early fracture union. Since titanium is more pliable than stainless steel, it can be used as a dynamic orthopaedic material. Titanium implants are lighter and allow controlled micromotion at the fracture site, which promotes early callus formation by reducing stress shielding. Moreover, the lower modulus of elasticity of titanium as compared with stainless steel makes titanium nails ideal for use in young human patients (Mahar *et al.,* 2004; Hunter, 2005; Singh *et al.,* 2006; El-Adl *et al* 2009).

Several studies reported use of titanium elastic nails (TENs) for long bone fracture fixation in children. However, there is paucity of literature on the stabilization of canine radius-ulna fractures using TENs. As TENs allow controlled movement at the fracture site; there by, ensuring optimum production of the external callus by reducing the shear and transforming it into compression and traction forces. Besides, fractures stabilized in biological fashion leads to early union with better functional outcome. Considering the advantages and paucity of literature, this study was aimed to evaluate TENs for the stabilization of distal radius-ulna fractures in young dogs.

MATERIALS AND METHODS

Ten dogs (5 male and 5 female), aged 12.60 ± 6.45 months (4-24 months) and weighing 14.09 ± 6.41 Kg (4.70-22.00 Kg) involving grey hound (7) and one each of crossbred, Pomeranian and Siberian husky suffering from distal radius-ulna fractures were studied. Fall during race was common finding in grey hounds while vehicular trauma was the reason in the others since 3.40 ± 4.5 days (1-15 days). Study was duly approved by the CPCSEA to conduct from October 2018 to October 2020.

Radiographs of the radius-ulna including elbow and carpal joints were obtained in lateral and antero-posterior views, preoperatively. Narrowest medullary canal diameter, length of distal and proximal bone fragment was measured using inbuilt caliper of the CR system. In addition contralateral healthy radius-ulna was also radiographed as a reference to assess the growth of the operated bone. Immediate postoperative radiographs were evaluated and graded (0-3; anatomic reduction to severe malreduction) for reduction and articular alignment as described by Cook *et al.* (1999). Subsequent radiographs obtained at various intervals (day 12th, 45th and 60th or whenever the case was presented) were evaluated for fracture reduction, implant stability, progress of fracture healing based on visibility of fracture line and callus formation along with complications, if any.

All fractures were stabilized under general anesthesia using butorphenol @ 0.2 mg/Kg, acepromazine @ 0.05 mg/Kg and atropine @0.04mg/kg, IM. General anesthesia was induced with inj. Propofol, IV @ 4mg/kg or 'till effect'. A cuffed endotracheal intubation was done and anaesthesia was maintained with 1-2% isoflurane in oxygen using partial rebreathing system. Injection cefotaxime was administered @ 20 mg/Kg, IV, intra-operatively. The dog was placed in lateral recumbency with the affected limb upper most and the surgical site (from the mid humerus to mid metacarpal) was cleaned and prepared aseptically.

The special orthopedic instruments used for TENs are described in the previous study (Sodhi *et al.,* 2021) were used. The radius-ulna fracture site was exposed, as described by Piermattei and Flo (1997) using cranio-lateral approach. Minimum dissection at the fracture site without disturbing periosteum (except minor nibbling of ulna) was done (Fig 1a and b). A pliot hole was created each at the medial and dorso-lateral sides of distal radial fragment. Two TENs of same diameter (except in Pomeranian, single pin was inserted) were inserted from the pilot holes in the distal radial bone in a normograde manner (Fig 1c). The diameter of each nail was assessed, preoperatively, as 30-40% of the narrowest medullary cavity of radial bone. In two cases, retrograde method (drilling from the site of fracture towards the distal end of bone) was required as normograde pin insertion was not successful due to formation of abnormal misdirection / tract.

This study involved distal third fractures of radius-ulna, so the technique described for the repair of mid diaphyseal fractures in children (El-Adl *et al.,* 2009) was modified *i.e* instead of metaphysis, the TENs were inserted from the distal radial epiphysis (involving growth plate as well) by making guide holes using pointed curved awl. As radius-ulna being weight bearing bones in dogs, so to achieve better stability instead of one nail each in radius and ulna (as followed in medical practice), two nails of same diameter were inserted into radial bone. Using bone chuck with extension rod and hammer, TENs were inserted from the distal end of the radial

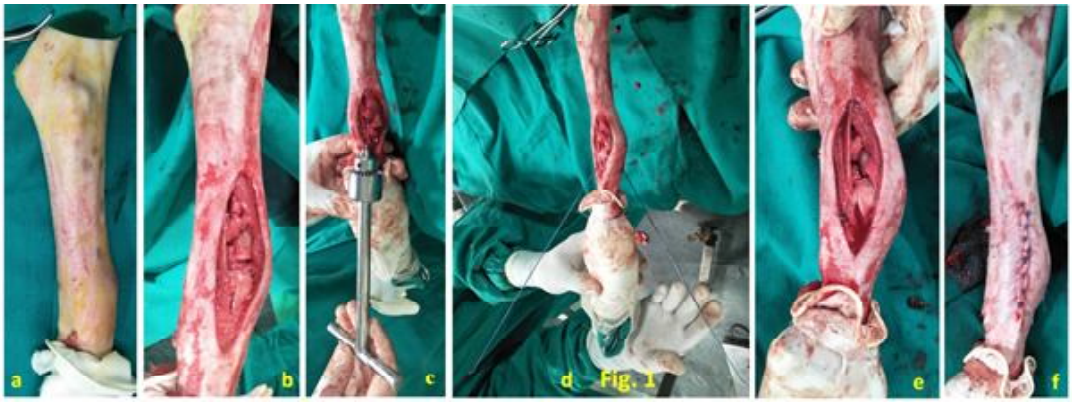

Fig 1: Serial radiographs to demonstrate the TENs technique to stabilize radius-ulna fracture.

(a) Aseptic preparation/draping of limb, (b) Making a cranio-lateral skin incision (c) Creating guide/pilot holes on lateral and medial sides of the distal fragment with awl or small pin secured in chuck, (d) Insertion of titanium elastic nails, (e) The nails protruding through the distal end of bone were bent and cut as short as possible with pin/wire cutter, (f) Closure of surgical wound.

bone up to the fracture site (Fig 1c) after which the fracture was reduced and the TENs were further driven proximally till the maximum proximal end (Fig 1d). No pre-contouring of the TENs (as described in literature) was done. The nails protruding through the distal end of bone were bent outwards using plier before cutting short (Fig 1e). This itself caused contouring of the nails to some extent (Fig 2b). Surgical site was thoroughly flushed before closure in a routine manner using polyglactin 910 no. 2-0 subcutaneously and skin using Nylon (Fig 1f). The ease of fracture reduction, type and size of implant, technique used, total operative time required (minutes) from skin incision to skin suturing and complications were noted.

Surgical wounds were dressed using Povidine Iodine and Neosporin powder on every 4th or 5th day intervals. A modified Robert Jones bandaging with PVC splint placed on the caudal side of limb was applied for 2 to 3 weeks. Postoperatively, all dogs were administered Cefotaxime @ 20 mg/Kg, bid, inj. Meloxicam @ 0.2 mg/Kg od, IM for 5 and 3 days respectively. Oral supplement consisting of Ca, P, Vitamin D3 and Vitamin B12 @ 1-2 tsp p.o. bid was recommended for 1 month. Cage rest and leash walking was advised for 15 days followed by passive exercise after 2-3 weeks. Skin suture removal advised after 12 days.

The range of motion (ROM) of the carpal joint was measured using metallic Goniometer at day 12, 45 and 60 by subtracting maximum flexion from maximum extension. The goniometric values were compared with contralateral healthy carpal joint. The operated dogs were assessed for weight bearing and functional usage of the affected limb while standing and walking/running. Total score was calculated by adding the scores obtained for weight bearing at standing and walking/running (range 0-6) as described previously (Cook *et al.,* 2010). Overall functional outcome was classified as full, acceptable, or unacceptable as defined as previously (Cook *et al.,* 2010).

All the operated cases were followed at various intervals to record recovery, minor and major (which lead to implant dislodgement or permanent deformity) complications. Out of 10, 3 dogs were presented for implant removal. The TENs were removed, aseptically, under general anesthesia. Stab skin incisions were made and the protruding distal ends of the pins were held with orthopedic plier and pulled out (Fig 2a, b and c).

Objective data were processed by computing mean ± SD using Microsoft excels and compared between various time intervals. The radial bone length (operated and healthy) between days 0 and 60 compared statistically using paired t-test.

RESULTS AND DISCUSSION

The idea of using TENs has been borrowed from the medical practice where this technique is routinely used for the management of long bone fractures in children (Mahar *et al.,* 2004; Hunter, 2005; Singh *et al.,* 2006; El-Adl *et al* 2009). As per authors, this is the first report on the clinical use of TENs for the stabilization of radius-ulna fractures in young dogs. The clinical use of TENs for femoral fractures in growing dogs has been recently published (Sodhi *et al.*, 2021).

Greyhounds have longest radius-ulna bones compared to other breeds kept in the region of study and are used for racing purpose which might be the reason for majority radius-ulna fractures in greyhounds. Higher incidence of radius-ulna fractures in racing greyhounds associated with bumping or hitting one another, or dogs hitting a rail or pole on the track surface are reported (Bloomberg and Dugger, 1988). Distal radial fractures in small and toy dog breeds are common and are usually reported with a high rate of complications including nonunion (Welch *et al*., 1997). Besides, distal radius-ulna fracture, particularly in heavy breed dogs, is prone to become open (Singh *et al*., 2021).

Radiographically, the fractures were either transverse (n=6) (Fig 3a and b) or short oblique (n=4) with a mean minimum diameter of medullary canal 4.40 ± 1.27mm (range 2.0-6.6 mm). The mean ± SD time required for TEN's placement was 64.50 ± 15.76 min (range 46-90 mins). The placement of TENs was easy in most cases (n=8). Since, adult dogs have narrow medullary cavity, so in two dogs

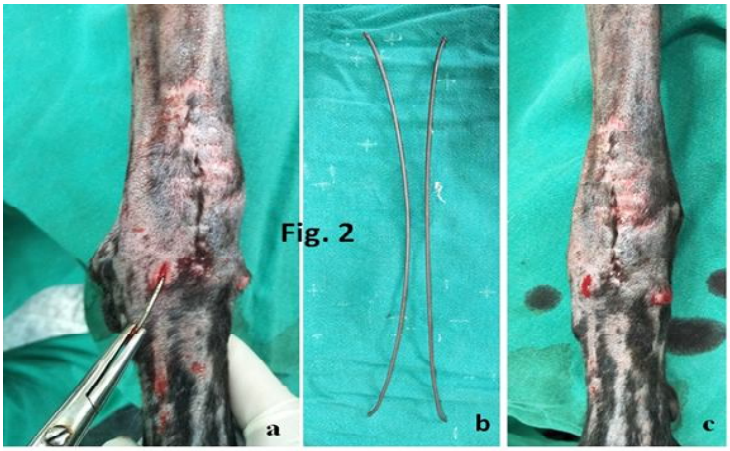

Fig 2: (a) Photograph showing pin removal through a stab incision by holding it with plier, (b) Photograph of removed titanium pins (c) Photograph showing two stab incision after pins removal in group 1a.

(aged 14 and 19 months), it was difficult to place TENS in normograde manner so TENs were placed in the distal fragment using retrograde method. The size of TENs used was 2 mm and 1 mm in 4 dogs each, while 1.5 mm in 2 dogs, (mean±SD 1.5±0.47mm for each nail) and pin to medullary canal ratio was 61.98±9.42% (45.40 - 75.00%). The medullary canal diameter of radial bone was narrow so it was possible to place comparatively small sized TENs (< 2 mm). Therefore young (with wider medullary canal) and light weighing dogs are most ideal.

Immediate postoperative radiographs reveals placement of TENs pins, symmetrically and to engage proximal bone fragment satisfactorily in majority of the fractures (6 out of 10) (Fig 3c and d). Whereas out of remaining 4 cases, TENs implant could not be placed satisfactorily, such as non-symmetric insertion of TENs pins into distal fragment in one dog, non-symmetric seating of TENs pins into proximal fragment (n=2) and placement of one pin only. Majority of the fracture showed grade 1 reduction (n=8) on immediate post-operative radiographs whereas one each showed grade 2 and 3 reduction.

Day 12 radiographs reveal stable implants in 8 dogs. Six dogs had evidence of uniform callus formation (16.00 ± 30.50mm long and 2.00 ± 2.83mm wide), but fracture line was visible whereas in the remaining callus formation was not appreciable. Two dogs had complications; one angulation at fracture site and in second pin break was recorded at day 12. Angulation at the fracture site was associated with the non-symmetric pins placement.

Surgical wound healed in all dogs on day 12 of surgery, but pain and inflammation was present. In 4 dogs operated with TENs small wounds were present at the pin insertion site. On day 45, pain and inflammation was present in 4 and 3 dogs, respectively and these also had implants related complications. On day 45, the length and width of callus was 22.80±12.34 mm and 3.50±2.69 mm, respectively. At 60 days length and width of callus was 26±5.57mm and 4.33±0.58mm, respectively (Fig 3e and f) was increased non-significantly.

No significant difference in the length of operated and contralateral healthy radial bone was noted on days 0 and 60. However, in comparison to operated bone on day 60 (202.67±6.68 cm), the mean length of contralateral healthy bone was non-significantly more (215.80±50.98 cm) indicating possible damage to the distal physis intraoperatively or during trauma.

Markedly reduced ROM of carpal joint was observed on day 12 (72.4 ± 29.24°) that improved non-significantly on day 45 (79.2 ± 35.77) and reached near normal at day 60 (106 ±9.64°) compared to contra-lateral healthy carpal joint (123.33 ±15.27°). During early follow up period, markedly reduced ROM of carpus in operated limbs could be due to pain associated reduced flexion angles whereas extension angles remained unaffected. During later stages of follow up (day 60), the functional outcome evidenced by better goniometry angles could be due to the fact that TENs were placed intramedullary and did not interfere with the extra osseous structure (Sodhi *et al.*, 2021). Gill *et al* (2018) reported better functional outcome and reduced stiffness of stifle joint associated with single end threaded pin as compared to cross pinning technique used to stabilize supracondylar fracture in dogs.

Weight bearing scores on walking increased gradually from 12th (1.62 ± 1.51) to 45thday (2.57±1.51) and day 60 (3.75±0.5) and full (4.0±0) at day 90. Lameness score was found non-significantly more on day 12 (4.12 ± 0.99) as compared to day 45 (2.88 ± 2.47) and day 60 (1 ± 1.55). Lameness score gradually decreases on day 45 and day 60 and 90, non-significantly.

Majority of the dogs (n=5) had no complication whereas in one each dog revealed complications like suture line infection along with angulation at fracture site (greyhound, male, 19 month), suture line infection with both the pins migrated distally and mild angulation (greyhound, female, 12 month), one pin (medial) migrated and exposed externally (greyhound, female, 18 month), pin breakage and in another dog, suture line infection was recorded. Majority of the complications (4 out of 5) recovered fully with conservative

Fig 3: Sequential radiographs showing fracture healing (a and b) Pre-operative radiographs showing distal third fracture of radius-ulna, (c and d) Immediate post-operative radiographs following fracture stabilized with TENS pins in symmetric fashion leading to excellent fracture reduction, (e and f) Evidence of fracture union and stable implant on day 60.

treatment or suitable surgical intervention except one grey hound male dog, aged 19 month showed angulation at fracture site leading to marked persistent lameness even on follow up of 9 months which could be associated with malunion. However, owner did not bring the dog for radiographic evaluation and pin removal. Long term follow up revealed resumption of full (n=9) and acceptable (n=1) functional outcome.

In one Pomeranian dog (14month) in which single TENS (1mm) could be placed in the radial bone had complication of pin breakage at the fracture site after 15 days. The broken distal TENS was removed after one month and the fracture was allowed to heal conservatively with full functional outcome after 2 months. In contrast, Prabhukumar *et al.* (2020) used single stainless steel elastic stable IM nail to stabilize radial of two young dogs, successfully, without any implant related complications.

The TENs is currently used in medical practice to stabilize long bone fractures in children in which two nails of same diameter are inserted symmetrically in a dynamic cross intramedullary fashion to achieve biomechanical stability from the divergent 'C' configuration that provides six points of fixation (3 point fixation with each nail). The nails are pre curved to about three times the narrowest (isthmus) diameter of bone to achieve dynamic stability (Hunter, 2005). The dense metaphyseal region of children's developing bones offers sufficient nail anchoring at entry points. By achieving axial and rotational stability, these nails decrease the chances of angulation in both anterio-posterior and varus/valgus (Singh *et al.* 2006) that helps to develop early bridging callus (Hunter, 2005). The TENs are especially effective for closed forearm fractures in children as intact muscle envelope around the injured bone provides biomechanical stability.

Distal migration of TENs, in the present study, could be due to the fact that nails were placed straight without pre-contouring; however, bending of nails outwards caused nails contouring to some extent itself (Fig, 2b, 3d and 3f). Instability due to asymmetric nails insertion could be the reason for wound related complications. Most of the complications were observed in dogs aged above 1 year and heavy weight dogs. Further studies involving large sample size and placement of an additional pin in the ulnar bone are warranted that may improve implant stability and may reduce complications. Despite better pin to medullary canal ratio (61.98±9.42%), higher complications were recorded in radius-ulna fractures which could be due to the limitation of use of smaller sized pins (due to narrow medullary canal), longer bones and heavier body weight of dogs.

CONCLUSION

The titanium elastic nails (TENs) were found suitable for the repair of distal radius-ulna fractures in young dogs due to broad medullary canals. Being dynamic fixation technique, it leads to bigger bridging callus with satisfactory carpal joint mobility. The TENs technique is simple and is recommended as an alternative fixation technique for distal radius-ulna fractures in young dogs. As per author, this is the first report on the use of TENs for the management of radius-ulna fracture in dogs. Further studies involving large sample size are warranted.

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