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Clinical study on the surgical management of tibial fractures using titanium elastic nails in dogs

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Abstract
The current study was undertaken to evaluate the clinical efficacy of Titanium Elastic Nails for repair of Tibial fractures in six dogs presented with fractures to the Department of Veterinary Surgery and Radiology at the College of Veterinary Science, Hyderabad. They were diagnosed by clinical signs, orthopaedic examination and survey radiography. The symptoms observed in hind limb of 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 mid diaphyseal transverse fractures in three dogs, mid diaphyseal short oblique fractures in two dogs, and mid diaphyseal simple spiral fracture in one dog. All fractures are closed, three in right hindlimb and three in left hindlimb. These fractures were stabilized with Titanium elastic nails of 2.0mm and 2.5 mm diameter were used for all the cases which provided adequate stabilization for open reduction internal fixation and resulted in remarkable improvement with normal limb function except in two dogs, were in one dog due to hyper activity of the dog, the fracture site was opened and fracture fragments got exposed. Whereas in another dog, due to weight more than 10kg and its hyperactivity and usage of staircase one nail was broken at fracture site and without any complications in other four dogs, complete functional limb usage was seen by 60th day. All dogs showed normal weight bearing at rest, while the weight bearing of the affected limb while walking 10th post-operative day, in 3 dogs, 15th post-operative day in 2 dogs and 30th post-operative day in one dog. 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 5.00±0.00, 3.16±0.40, 2.66±0.51, 2.16±0.75, 1.50±0.83 and 1.33±0.81 respectively. The mean age of the dogs to bear the complete weight on the affected limb were seen on 15±7.74 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 the 60th post-operative day revealed dense callus of reduced size; fracture line disappeared and the callus became radio-dense with clear establishment of cortico-medullary canal. And on the 90th post-operative day revealed distinct cortico-medullary separation caused by remodelling, restitution of the cortico-medullary canal is completed and which is well appreciated on a radiograph by 60th and 90th post-operative days respectively. Based on present study, it is concluded that Titanium Elastic Nailing was successful in the treatment of diapyseal tibial fractures in dogs as it is lighter in weight, had superior fatigue and corrosive resistance, improved biocompatibility and lower young's modulus.

Keywords: Titanium elastic nails, tens, internal fixation, biocompatibility, tibial fracture repair, dogs, canines

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]. Other workers reported the fractures in hind limb were highest in femur, followed by radius-ulna, tibia and humerus fractures and other bones [3, 4].

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. Various internal fixation devices have been used to repair the long bone fractures depending upon the stability required.

For tibial diaphyseal fractures different treatment modalities are external coaptation, external skeletal fixation, intramedullary pins, interlocking nails, bone plating, lag screws, cerclage wiring etc. Historically, external fixation has been the treatment of choice; however, risks include pin-track infections, nonunion and refracture. Reamed locked intramedullary nails, while shown to be effective in the skeletally mature, pose unnecessary risk to the proximal tibial physis, and have limited indications in those children with growth remaining [5].

Titanium elastic nails achieve biochemical stability from the divergent "C" configuration which creates six points of fixation and allows the construct to act as an internal splint. Also provide suitable and elastic fixation, allowing for controlled motion at the fracture site which results in healing by external callus [6]. The principles, indications and surgical technique of elastic stable intramedullary nailing for fractures in children [7]. According, this minimally invasive technique, two elastic nails were introduced into the medullary canal, advanced through the fracture site impacted into the opposite metaphysis. These nails performed in a C-shaped manner, which allowed precise orientation and created an elastic stable system that resisted deformation; but in veterinary practice, very few reports are available. Due to paucity of literature, the use of titanium elastic nails in the treatment of tibial fractures in dogs was undertaken to record its clinical efficacy.

Materials and Methods

Anamnesis

The dogs presented for treatment of tibial fractures occurs in Mongrel dogs (3) followed by one each in Beagle, Spitz and Chippipari 'breeds of dogs. Whereas the age ranging from 4 months to 8 months, body weight of dogs ranging from 5-15 kg. and sex predisposition in male dogs. The mean time of gap between the time of fracture and treatment was 4±1.78 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 of tibial fractures in dogs.

Case No.	Breed	Age (Month)	Sex	Body wt. (kg)	Cause of fracture	Days since injury
1	Beagle	8	Male	7	Sudden twist	4
2	Mongrel	5	Male	6.5	Automobile accident	3
3	Mongrel	4	Male	4.7	Automobile accident	5
4	Spitz	6	Male	5	Hit with stick	7
5	Mongrel	6	Male	8.5	Hit with stone	2
6	Chippiparai	7	Male	15	Fight with pig	3
		6.00±1.41	Male	7.78±3.79		4±1.78

Pre-Operative Observations

Pre-operative Clinical Observations

On clinical examination all the dogs were assessed for pain, local swelling, loss of function and crepitation at the fracture site. Deep pain perception was evaluated in all; none of the dogs had any neurological deficit since all of them responded at good or fair levels on pinching of the paw. Crepitation could be easily felt with the pressure exerted by finger tips. Change in angulation of the limb in the form of deformity was observed. Dangling of distal part of hind limb below the fracture line was noticed in one dog with long oblique fracture. (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.

Fig 1: Non weight bearing of the fractured limb pre-operatively Grade V lameness.

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].

Classification of tibial diaphyseal fractures in the present study was done [9] and classification system and details including limb affected, open or closed fracture, location of fracture and type of fracture were given in table.2 In the present study the dogs with tibial fractures were classified as mid diaphyseal transverse fractures in three dogs, mid diaphyseal short oblique fractures in two dogs, and mid diaphyseal simple spiral fracture in one dog. Pre-operative radiographs of the dogs with tibial fractures were presented in fig.2. The details regarding the fractures encountered in all the dogs are presented in Table 2.

Table 2: Pre-operative Radiological Observations (Titanium Elastic nailing technique)

Case No.	Limb affected	Open or closed	Location of fracture	Type of fracture
1	Right hind limb	Closed	Mid diaphyseal	Complete short oblique fracture
2	Left hind limb	Closed	Mid diaphyseal	Complete short oblique fracture
3	Left hind limb	Closed	Distal diaphyseal	Complete transverse fracture
4	Right hind limb	Closed	Mid diaphyseal	Simple spiral fracture
5	Right hind limb	Closed	Mid diaphyseal	Complete transverse fracture
6	Left hind limb	Closed	Mid diaphyseal	Complete transverse fracture

Case 1: Cranio-caudal view **Case 2:** Cranio-caudal view **Case 3:** Cranio-caudal view

Case 4: Cranio-caudal view **Case 5:** Cranio-caudal view **Case 6:** Cranio-caudal view

Fig 2: Skiagram showing pre-operative radiographs of all six dogs

Planning of Surgery

Measurements obtained from the pre-operative radiographs of normal contralateral limb were used to select the length of titanium elastic nails and diameter of the nails. Fig.3

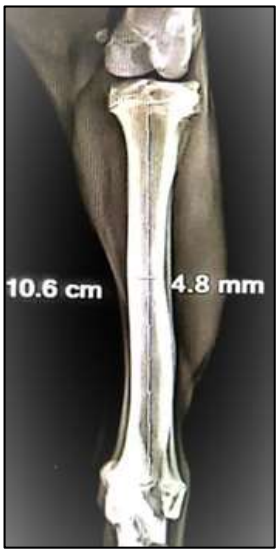


Fig 3: Skiagram of normal contralateral limb showing measurement of length of the tibia and medullary diameter at the isthmus

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. Ten minutes later, general anaesthesia was induced with intramuscular injection of ketamine hydrochloride at the rate of 10 mg/kg body weight. 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.

Materials Used

Orthopaedic Instruments

A general surgical instrument set and orthopaedic instruments as needed for a Titanium elastic nailing technique.

Implants

In the present study titanium elastic nails of 2.0 mm, 2.5 mm were used for the stabilization of the fractures (Fig. 4). The diameter of the nail was 30-40% of the diameter of the medullary cavity and both the nails chosen were of identical diameter in order to avoid valgus or varus mal-positioning. Pre-bending of the nails to three times the diameter of the medullary canal was done inorder to increase the pressure applied internally, thus shifting the nail cross over points more towards the metaphysis which would increase the stability of complex fractures (Fig. 5).

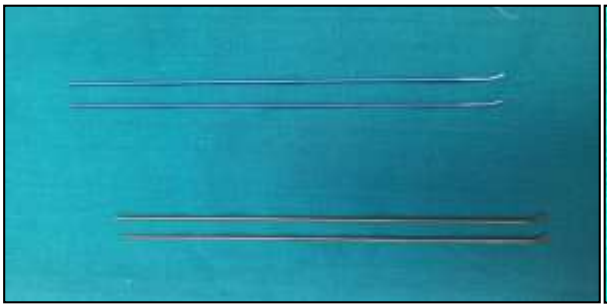


Fig 4: Titanium elastic nails

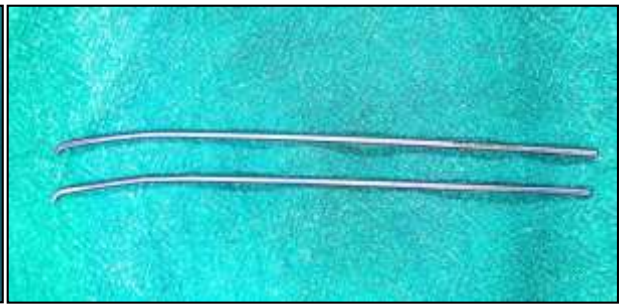


Fig 5: Prebending of nails

Positioning of the Animal

The dogs with fractures of tibia were positioned in lateral recumbency with the fractured limb down and the contralateral limb secured out of the way. Sterile drape was applied in such a way that it exposed only the affected limb. Distal extremity of the limb with fracture of tibia was covered completely with sterile bandage cloth distal to the tarsals. The entire operative site was again painted with 5% povidone iodine solution followed by application of surgical spirit and draped.

Indirect fracture reduction by hanging limb technique as suggested [10] was used while performing titanium elastic nailing since the fracture site was not exposed. The animal was positioned in dorsal recumbency with the affected limb suspended from the ceiling by a sterile snap hook system which facilitates surgeon to disconnect the limb from the anchorage point to evaluate joints flexion and plane of motion. By lowering the surgical table, the animals own weight distracts the fracture to ensure adequate fracture reduction.

Surgical Procedure

The first stage of this type of osteosynthesis was the obtaining of the closed reduction of the fracture by external manipulation and hanging limb method. If closed reduction was not possible, then open reduction was achieved with limited incision at the fracture site. (Fig. 6 and Fig. 7) And as per the approach to the tibia at the level of metaphysis in cranio-medial and caudo-lateral incisions for the point to insertion for titanium elastic nails as described [11].

The classical approach was at the level of the metaphysis, avoiding growth cartilage injury. Initially locate the nail insertion points on the tibia which were around 1 cm distal to proximal epiphyseal plate on either side of the tibial tuberosity.

At the planned insertion point, 1-2 cm linear incision was made on the medial side depending on the length of the bone for fracture reduction (Fig. 8 and Fig.9). Incision of same length was made on the lateral side (Fig.10). These insertion points were made outside the joint capsule in order to avoid the epiphyseal plates.

With the use of corresponding drill bit, medullary cavity was opened at the point of insertion of nail. The opening made was slightly larger than the selected nail diameter. The same procedure was repeated on the opposite side.

The nail was then inserted into the medullary cavity with the nail tip at right angles to the bone shaft. Then pin inserter was turned through 180^{o} in order to align the nail tip with the axis of the medullary cavity.

Progression into the medullary canal was facilitated by the oscillating rotation movements of the hand piece (Fig.11). Advancement should be easy, without forcing the penetration of the nails with the hammer, which might cause the perforation of the compact bone or even a new fracture. Using rotating movements or gentle taps of the hammer, nail was advanced manually upto the fracture site.

Similarly the second nail was inserted and advanced to the fracture site (Fig. 12) The two nails were advanced symmetrically up to the fracture site (Fig.13). At this point, fracture reduction was performed after which one of the nails was inserted through the fracture site into the distal bone fragment. Similarly the second nail was advanced up to the level of the opposite metaphysis.

Once the fracture was firmly fixed, check rotation and then nails were trimmed (Fig. 14). Sharp edges of the nails were made blunt with rasp (Fig.15). Then nail was advanced to the final position by gentle taps. The incisions were closed routinely subcutaneously with Vicryl 2-0 by simple continuous suture pattern and then skin with polyamide No. 2-0 in a cross-mattress fashion (Fig. 16 to Fig.18).

Post-Operative Care and Management

Sutured wound was covered with sterile cotton and gauge pad impregnated with 5% povidone iodine solution to protect surgical site from infection and to minimize the swelling. In all dogs under study, additional cotton padding was rolled on the limb from toe to groin region. Gauge wrap and surgical paper tape were then applied over the cotton padding. The padding was changed every day for 5 days and then alternate days until suture removal. Inj. Ceftriaxone sodium at the rate of 20 mg/kg body weight was given intramuscularly twice daily for one week and Inj. Meloxicam at the rate of 0.2 mg/kg body weight was given subcutaneously for four days post-operatively. Owners were advised to restrict the movement of the animal for 10 days and then to allow for leash walking.

Fig 6: Medial proximal incision for nail insertion and limited incision at fracture site for fracture reduction

Fig 7: Exposure of fracture fragments

Fig 8: Initial Fracture reduction

Fig 9: Insertion of first titanium elastic nail from medial proximal incision

Fig 10: Lateral proximal incision for second titanium elastic nail

Fig 11: Insertion of second titanium elastic nail from lateral incision

Fig 12: Advancement of nail by oscillating movements

Fig 13: Advancement of second nail to the fracture site

Fig 14: Trimming of nail after fracture fixation with nails

Fig 15: Rasping of sharp cut ends of nail

Fig 16: Closure of medial side incisions with subcuticular sutures

Fig 17: Closure of lateral incision with subcuticular sutures

Fig 18: Skin closure with cross mattress suture pattern

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.

Lameness grading

All six dogs in the present study showed partial weight bearing on 1st post operative day. All dogs showed normal weight bearing at rest, while the weight bearing of the affected limb while walking 10th post-operative day, in 3 dogs, 15th post-operative day in 2 dogs and 30th post-operative day in one dog. 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 5.00±0.00, 3.16±0.40, 2.66±0.51, 2.16±0.75, 1.50±0.83 and 1.33±0.81 respectively. The mean age of the dogs to bear the complete weight on the

affected limb were seen on 15±7.74 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 3.

Table 3: 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	III	II	I	I	I	10th day
2	V	III	II	II	I	I	10h day
3	V	III	III	II	I	I	10th day
4	V	III	III	II	I	I	15th day
5	V	IV	III	III	II	I	15th day
6	V	III	III	III	III	III	30th day
	5.00±0.00	3.16±0.40	2.66±0.51	2.16±0.75	1.5±0.83	1.33±0.81	15±7.74

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

Grade II lameness (10th Post –operative day) Case .1 | Grade II lameness (10th Post –operative day) Case.2 | Grade III (10th Post –operative day)

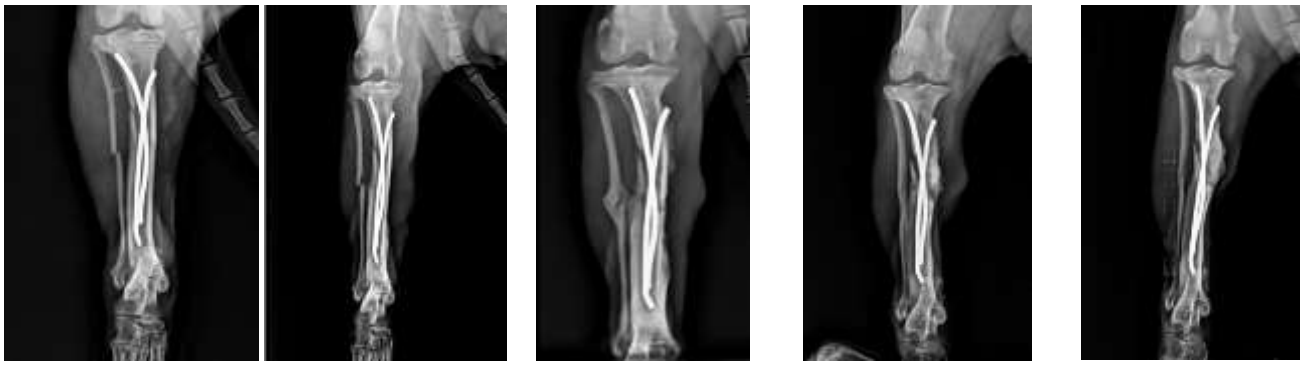
Grade III (10th Post –operative day) | Grade III (10th Post –operative day) | Grade III (10th Post –operative day)

Fig 19: Different post-operative weight bearing of the affected limb in all six dogs

Post-Operative Radiographic Observations

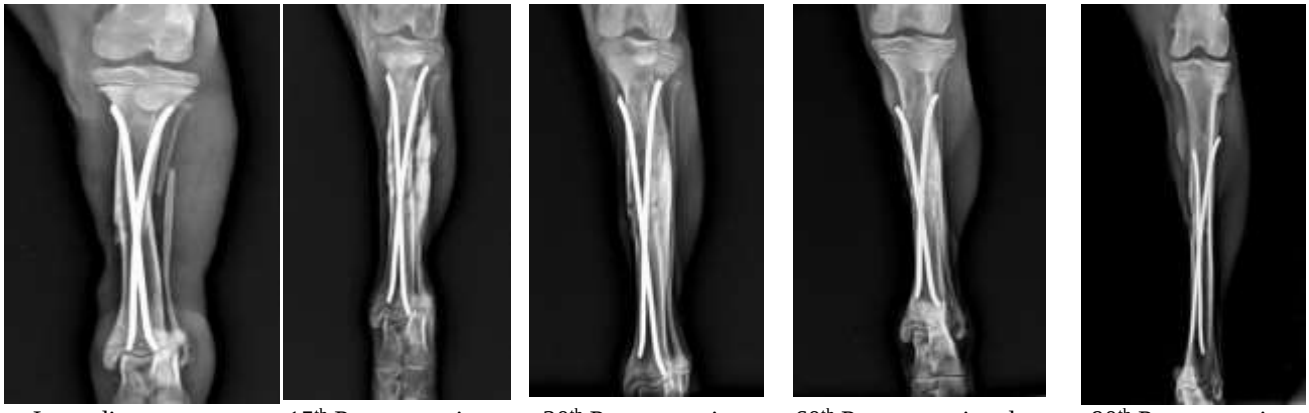
Immediate post-operative radiographic evaluation confirmed proper placement of Titanium elastic nail, with good apposition of the fractures fragments in all the six dogs. Follow-up radiographs obtained on the 15th post-operative day depicted proper position and good alignment of the fracture fragments in all dogs however the radiolucent fracture line was still discernible in all the cases. The radiograph revealed minimum callus formation bridging the fracture site. Radiographs obtained on the 30th post-operative day revealed bridging callus reduced in size. The callus was smoother and opaque. Radiolucent fracture line was faintly visible. Radiographs obtained on the 60th post-operative day revealed dense callus of reduced size; fracture line disappeared and the callus became radio-dense with clear establishment of cortico-medullary canal. Radiographs obtained on the 90th post-operative day revealed distinct cortico-medullary separation caused by remodelling, 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. 20 to 22. In this group it is depicted fracture healing on the radiographic scoring [13] in all dogs in table 4.

Signs of mild to moderate weight bearing lameness were noticed in case four. Due to spiral nature of fracture and hyper activity of the fracture site was opened and fracture fragments got exposed (Fig.23). In case six, though 2.5mm titanium nails used due to large breed and beyond 10kg weight and over activity and usage of staircase one nail was broken at fracture site (Fig.24). Supported with welcast/fiberglass bandage and instructed owner to reduce activity and avoid staircase, eventhough after a week the second nail too broken at fracture site.



Immediate post – operative day | 15th Post-operative day | 30th Post-operative day | 60th Post-operative day | 90th Post-operative day

Fig 20: Skiagram showing the progression of fracture healing in case.1



Immediate post – operative day | 15th Post-operative day | 30th Post-operative day | 60th Post-operative day | 90th Post-operative day

Fig 21: Skiagram showing the progression of fracture healing in case.2

Immediate post –operative day case.1 | 15th Post-operative day | 30th Post-operative day | 60th Post-operative day | 90th Post-operative day

Fig 22: Skiagram showing the progression of fracture healing in case.3

Table 4: Details of Radiological scoring in all dogs in this group

Case No.	Day 0			30th Day			60th Day			90th Day		
	Fracture alignment	Callus formation and cortical continuity	Radiological score	Fracture alignment	Callus formation and cortical continuity	Radiological score	Fracture alignment	Callus formation and cortical continuity	Radiological score	Fracture alignment	Callus formation and cortical continuity	Radiological score
	Group-I Titanium elastic nailing technique											
1	+	-	3	+	+++	1	+	+++	1	+	+++	0
2	+	-	3	+	+++	1	+	+++	1	+	+++	0
3	+	-	3	+	+++	1	+	+++	1	+	+++	0
4	+	-	3	+	++	1	+	++	1	+	++	1
5	+	-	3	+	++	1	+	+++	1	+	+++	0
6	+	-	3	+	++	1	+	+	2	+	+	3

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 radiiographic healing , '1'-Appropriate progression towards healing, but not completely healed, '2'-Inappropriate progression towards healing , '3'- No evidence of healing, failure

Discussion

In the present study, out of the six cases, the prevalence of tibial fracture in different breeds was as follows, mongrel (50 %) followed by beagle (16.6%), spitz (16.6%) and chippapari (16.6%). Our findings were in accordance with other who observed highest incidence of fractures in non-descript dogs which might be due to their free roaming habit making them more vulnerable to road accident [14]. Also reported that the fractures were highest in Non-descript dog followed by descript dogs[15]. In contrary, the highest incidence was recorded in Labrador followed by German shepherd, Spitz, Doberman and Mongrel dogs [16].

In the present study titanium elastic nails of 2.0 mm, 2.5 mm were used for the stabilization of the fractures. The diameter of the nail was 30-40% of the diameter of the medullary cavity and both the nails chosen were of identical diameter inorder to avoid valgus or varus mal-positioning. Pre-bending of the nails to three times the diameter of the medullary canal was done in order to increase the pressure applied internally, thus shifting the nail cross over points more towards the metaphysis which would increase the stability of complex fractures. The titanium elastic nails have advantage over stainless steel nails as they have more biocompatible, elastic properties, and bend to extent and regain shape to give stability of the fracture fragments. This in congruence with opinion of other workers [17, 18, 19, 20, 21, 22, 23, 24].

All six dogs in the present study showed partial weight bearing on 1st post-operative day. All dogs showed normal weight bearing at rest, while the weight bearing of the affected limb while walking 10th post-operative day, in 3 dogs, 15th post-operative day in 2 dogs and 30th post-operative day in one dog. 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 5.00±0.00, 3.16±0.40, 2.66±0.51, 2.16±0.75, 1.50±0.83 and 1.33±0.81 respectively. The mean age of the dogs to bear the complete weight on the affected limb were seen on 15±7.74 days.

Lameness grading was superior in all the 4 dogs whereas in one dog due to hyper activity, the fracture site opened and fracture fragments got exposed. Whereas in another dog, due to weight more than 10kg and its hyperactivity and usage of staircase the titanium elastic nail was broken at fracture site, However, implant stability throughout the observation period in other 4 dogs was remarkable. This is in congruence with [25, 26, 27].

The Immediate assessment of post-operative radiographic evaluation confirmed proper placement of Titanium elastic nail, with good apposition of the fractures fragments in all the six dogs. Based on the presence of progressive changes in radiographs on 15th, 30th, 60th and 90th days mineralized cortical bridging callus, bone formation at the fracture site, fracture line disappearance, and cortical continuity, and the callus became radio-dense with clear establishment of cortico-medullary canal with complete bone formation in 4 dogs except in 2 dogs where in exposure of fracture fragments, breakage of titanium elastic nail at 30th day post-operatively. These findings are in congruence with [3, 28, 29].

Whereas Titanium elastic nails as in described procedure that the nails was then inserted into the medullary cavity with the nail tip at right angles to the bone shaft from both cranio-medial and caudo-lateral at the proximal site of tibial bone, Progression of titanium elastic nails into the medullary canal was facilitated by the oscillating rotation movements of the hand piece. Titanium elastic nails achieve biomechanical stability from the divergent 'C' configuration which creates six points of fixation and allows the construct to act as an internal splint which neutralizes all fracture forces in young dogs weight less than 10kg. These findings are in congruence with other researchers [30, 31, 32, 33].

The complications which recorded in the present study, were unusual. In contrary, most others recorded common complications with intramedullary pinning were pin migration. infection, implant failure, delayed union, non-union, malunion and osteomyelitis [34, 35].

Conclusion

Based on present study, it was concluded that Titanium Elastic nails (TENs) was successful for the repair of tibial fractures in young dogs and offered good recompense and remarkable improvement in the limb function, with good fracture stability till the completion of the bone healing The application of TENs 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 TENs technique, 4 dogs had no complications, and other two, one had fracture ends distracted and another dog had titanium nail broken at the fracture site.

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