INTERNATIONAL JOURNAL OF ADVANCED BIOLOGICAL RESEARCH

www.scienceandnature.org

OCCURRENCE, CLASSIFICATION, METHODS OF FIXATION AND OUTCOME OF LONG BONE FRACTURES IN DOGS: A REVIEW OF 342 CASES

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ABSTRACT
The study was conducted on 363 long bone fractures in 342 dogs to investigate the factors affecting occurrence, etiology of fracture, methods of fracture fixation, overall clinical outcome and complications. Considerable variations were observed with respect to factors like age, sex, breed, etiology, time lapse, bone affected, nature, position and orientation of fracture, mode of repair and outcome of the treatment. Intramedullary pinning (107) was the most common method of surgical fracture repair, followed by locking compression plating (56), external skeletal fixation (24) and interlocking nailing (15). External coaptation was used in 132 animals having fractures below shoulder and stifle. Among 228 fractures treated surgically, 198 fractures showed good outcome after surgery, with 12 patients experiencing major complications, whereas follow up of 16 animals was unavialable. Puppies aged 4 months and above were considered for intramedullary pinning of humeral and femoral fractures. Locking compression plating was found stable internal fixator method for radial, femoral and tibial fractures which results in satisfactory load sharing and implants stability which leads to primary gap healing or healing under callus formation when proper principles of application are followed. For adult dogs with unstable diaphyseal femoral fractures interlocking nailing or plate-rod construct was preferred internal fixation method using a locking compression plate and intramedullary rod of 30-40% of medullary diameter. ESF with acrylic connecting bars was preferred fixation technique for open fractures of radius-ulna and tibia which resulted in secondary bone healing and restoration of limb function.

KEY WORDS: fracture, occurrence, classification, fixation, dogs.

INTRODUCTION

Trauma is the most common cause of fractures in canines, causing bending, torsional, shear and rotational forces which eventually result into oblique, spiral, segmental, spiral and wedge fractures. Femur is most commonly affected bone for fractures followed by tibia and radius-ulna (Harasen, 2003). Primary objective of fixation in stable fractures (eg. transverse, greenstick and impacted) is to prevent angular and rotational deformity. Whereas in unstable fractures (*e.g.* oblique, nonreducible wedge) fixation must be aimed to maintain length, alignment and to counteract angular and rotational forces (Piermattei *et al.,* 2006). The common complications in fracture treatment include fracture instability, implant migration, implant failure and implant rotation, which can be overcome by using newer techniques like intramedullary interlocking nailing. The intramedullary nails improve stabilization of the fracture and limit bending forces, fragment rotation and fracture collapse (Duhautois, 2003). Bridging osteosynthesis technique is less time consuming and results in faster healing for the repair of highly comminuted fractures compared with fragment reconstruction and bone plate application (Hulse & Johnson, 1997). Addition of IM pin to a bone plate decreases strain on the plate two fold and subsequently increases the fatigue life of the plate-rod construct 10-fold compared with that of plate alone (Hulse *et al.*,1997). The objective of the present study was aimed to investigate the factors affecting occurrence, etiology of fractures, methods of fracture fixation, clinical outcome and complications of canine long bone fractures treated with different techniques at Referral Veterinary Polyclinic of the Institute.

MATERIALS AND METHODS

All the animals presented for fracture treatment were analyzed based on case history, client data, observations, clinical records, survey radiographs and subsequent follow up radiographs. Client data about time lapse between fracture occurrence and presentation, cause of fracture and age of the animal were surveyed. Clinical data were categorized as breed, gender, bone affected, type of fracture, cause of fracture, modality of treatment and outcome. Evaluation of radiographs was done to analyze fracture configuration. Radiographs were utilized to categorize the fracture based on the Unger system of classification (Unger *et al.,* 1990). Sequential follow up clinical evaluations and radiographs were used to investigate the outcome in terms of complications. Minor and major complications were recorded as defined by Dvorak et al.(2000). With misalignments, hypertrophic callus, mild arthrosis, delayed union as minor complications and severe arthrosis, non-union, osteomyelitis, implant failure as major complications.

Stabilization description

External coaptation technique like Thomas splint, Robert-Jones bandaging, application of plaster of paris and

fibreglass acrylic cast were used to treat 132 cases. Among 132 long bone fractures treated by external coaptation, 55.6% of the animals were under 6 months of age and 15.9% of animals were 6-12 months old.

Suitable internal fixation method was applied depending upon age of the animal, body weight, type of fracture, breed of dog. Animals were subjected to surgical treatment in lateral recumbency with affected limb uppermost, using lateral approach to humerus, craniolateral approach to radius, craniolateral approach to femur and medial approach to tibia (Piermattei and Greeley, 1993). Following surgical methods were used to treat the fractures as per the merit of the case.

Intramedullary pinning

Simpletransverse and short oblique diaphyseal fractures of humerus, femur and tibia were treated with intramedullary pinning (Fig. 1A & B). A Steinmann pin with three pointed trocar was placed in normograde manner in most of the cases. In oblique fractures, the fragments were reduced and bone alignment was maintained by circlage or hemicirclage wires. In adult dogs with long oblique, spiral, wedge or segmental fractures were subjected to ILN or bone plating.

Bone plating

Bone plating was done with 2.7mm or 3.5mm locking compression plates (Nebula surgicals, Ahmedabad, Gujarat, India). All holes of locking head screws were drilled with appropriate drill guide to ensure correct angulation. A 2 mm drill bit for 2.7 mm locking screws and 2.7mm drill bit for 3.5 mm locking screws were used. A torque limiting screw driver and self-tapping corresponding locking screws of 2.7mm or 3.5mm were used. Radial fractures were treated with 3.5mm, locking compression plates by applying at the cranial surface of the radius in 12 cases. Whenever interfragmentary compression was desired, the LCP was used as a hybrid construct with combi hole technique. In case of wegde fractures LCP was used as bridging plate.

For femoral fractures plate-rod method was followed using 2.7mm or 3.5mm locking compression plates along with intramedullary rod of 30-40% of diameter of medullary cavity as a plate-rod construct in 39 cases (Fig. 2A & B). In short breeds of dogs like Spitz, Pug, Pomeranians and puppies of medium or large breeds ageing above 5 months, weighing around 10-13 kg body weight a 6-8 hole x 2.7mm x 8mm locking compression plate was used. In adult dogs weighing 13-35 kg, a 8-10 hole x 3.5mm x 11mm locking compression plate which is equal to length of contralateral femur predetermined by preoperative radiographs were used.

For tibial fractures a 6-8 hole x 3.5 mm x 1mm locking compression plate was applied in medial side of the bone in six animals either as neutralization plate or bridging plate depending upon the fracture configuration (Fig. 3).

Selection of LCP was done based on the patient size, contra lateral bone length, fracture configuration and surgeon preference. Using pre operative radiographs of contralatereal limb in two views, decisions were made before surgery about precise positioning of the plate, size and length of the plate, necessity of contouring to achieve angular stability of the locking screw. Self tapping screws were used in all cases. Animals above 5 months of age were considered for bone plating and LCP application was done excluding physis and epiphysis of the bone. Post operative fracture reduction was evaluated by radiograph for transitional malalignment i.e., mediolateral and craniocaudal displacement of the bone fragment in relation to the proximal fragment. Post operatively, Robert-Jones bandage was applied in all the animals up to 15 days.

Interlocking nailing

Long oblique, non reducible wedge and segmentaldiaphyseal femoral fractures were treated with interlocking nailing in 16 animals (Fig. 4). Standard veterinary interlocking nails of appropriate lengths 160-220 mm and 5-8mm in diameter were used with self tapping locking bolts of 3.5 mm diameter. The interlocking nail was placed in medullary cavity under the guidance of Steinmann pin and then interlocking nail was locked by bolts with the help of external aiming device (Jig). Both static and dynamic methods were followed for bolt application.

External skeletal fixation

Open fractures of radius-ulna and tibia in animals aged above 6 months were treated with external skeletal fixation in bilateral biplanar fashion with acrylic connecting bars. Smooth trocar pointed K-wires of 2 and 2.5mm diameter stainless steel were used for ESF application. Out of 26 compound fractures 24 were treated with external skeletal fixation (Fig. 5).

Cross intramedullary pinning

Supracondylar fractures (SCF) of femur were treated by cross intramedullary pinning. Following reduction of fracture fragments proper sized k-wires were passed first from medial aspect of medial condyle directing towards the lateral aspect of proximal fracture fragment. Second pin was passed from lateral aspect of lateral condyle directing in the reverse direction of first pin. Pins were pushed alternatively at such angles that both emerged out from the proximal fragment at intertrochanteric fossa of the femur. Whereas rush pinning was performed in one case of SCF.

Outcome evaluation

Progress of fracture healing was evaluated radiographycally for 3-4 months post surgery. Bone union was defined as the point when bridging callus was present or when the fracture line is no longer visible. Owners or referring Veterinarians were contacted for 120 days post surgery for long term follow up.

Statistical analysis

Frequency data were collected and expressed in percentage of the total long bone fractures using SPSS software. Statistical associations between the various recorded factors were analyzed using Chi-square test at a confidence level of 95%. Subsequently, frequencies with adjusted residuals with a value of 1.96 or greater, or -1.96 or less were considered significant at 95% level of confidence (Everitt, 1980).

RESULTS

A total 4716 cases of canine species were presented at Referral Veterinary Polyclinic, Indian Veterinary Research Institute, Izatnagar, Bareilly from July 2017 to Dec 2018 were recorded. Out of these 4716 cases, 363 long bone fractures were recorded in 342 canine patients which

constituted 7.25% occurrence of canine long bone fractures.

Breed

Highest number of fracture cases were recorded in non-descript (38.6%, 132) dogs followed by German Shepherd (13.2%, 45), Labrador (12.6%, 43), Indian Spitz (11.1%, 38), Pomerinarian (5.8%, 20), cross breed (4.7%, 60), Rottweiler (3.8%, 13), Pug (3.5%, 12), Lhasa and Pittbull terrier (1.2%, 4) each, Golden Retriever, Mastiff and Beagle (0.6%, 2) each, and least in Boxer, Cocker Spaniel and Pakistani Bully (0.3%, 1) each.

Age

The mean age of dogs presented was 20.13±1.66 (Mean±SE) months, ranging from 1month to 16 years. The highest numbers of cases were reported in dogs less than six months (37.7%, 129) of age followed by the age group of 6-12 months (29.2%, 100), 1-2 years (12.6%, 43), more than 3 years (16.4%, 56) and 2-3 years (4.1%, 14) as mentioned in Table-1 also against each bone wise.

TABLE1: Age wise occurrence of fractures in different bones affected

Age group	Value	Bone affected: No. of cases (percentage %)					TOTAL
		Femur	Humerus	Multiple bones	Radius-ulna	Tibia Fibula	
Less than 6 months	Frequency percentage	47(36.4%)	7(5.4%)	13(10.1%)	24(18.6%)	38(28.5%)	129(100%)
6 to 12 months	Frequency percentage	44(44%)	4(4%)	1(1%)	23(23%)	28(28%)	100(100%)
1 to two years	Frequency percentage	14(32.6%)	1(2.3%)	1(2.3%)	21(48.8%)	6(14%)	43(100%)
2 to 3 years	Frequency percentage	4(28.6%)	1(7.1%)	0(0%)	6(42.9%)	3(21.4%)	14(100%)
More than 3 years	Frequency percentage	12(21.4%)	2(3.6%)	4(7.1%)	24(42.9%)	14(25%)	56(100%)
TOTAL		121(35.4%)	15(4.4%)	19(5.6%)	98(28.7%)	89(26%)	342(100%)

TABLE 2: Bonewise distribution of fracture types within each long bone region

Bone	Fracture Position	Fracture Orientation						
		No. of cases	Wedge	Long Oblique	Multiple	Short Oblique	Spiral	Transverse
Femur	Epiphyseal proximal	8	12.5%	-	-	50%	-	37.5%
	Diaphyseal proximal	12	50%	8.3%	-	41.7%	-	-
	Mid diaphyseal	48	31.3%	4.2%	4.2%	31.3%	-	29.2%
	Distal diaphyseal	44	38.6%	-	-	15.9%	-	45.5%
	Distal epiphyseal	22	-	-	-	41.7%	-	58.3%
Humerus	Diaphyseal proximal	3	-	-	-	33.3%	-	66.6%
	Mid diaphyseal	11	9.1%	-	-	18.2%	18.2%	54.5%
	Distal diaphyseal	5	20%	-	-	-	20%	60%
Radius-ulna	Epiphyseal proximal	3	-	-	-	66.6%	-	33.3%
	Diaphyseal proximal	5	40%	-	-	40%	-	20%
	Mid diaphyseal	31	29.9%	3.2%	-	35.5%	-	32.3%
	Distal diaphyseal	66	9.1%	3.0%	-	37.9%	-	50%
	Distal epiphyseal	5	-	-	-	60%	-	40%
Tibia	Epiphyseal proximal	5	-	-	-	20%	-	80%
	Diaphyseal proximal	24	8.3%	25%	-	37.5%	-	29.2%
	Mid diaphyseal	39	25.6%	2.6%	-	38.5%	-	33.3%
	Distal diaphyseal	29	20.7%	-	-	37.9%	-	47.4%
	Distal epiphyseal	1	-	-	-	-	-	100%

Sex

Male (65.5%, 224) dogs were found to be more affected with fractures than female (34.5%, 118) dogs of all the age groups in the present study.

Etiology

The leading cause of fracture of long bones in the present study was automobile accidents (49.4%, 169) followed by fall from height (40.1%, 137), other causes (4.7%, 16) (indoor injuries, limb trapped in the door, accidental step by the owner, bicycle or furniture fall), abuse or malicious

injuries (2.9%, 10), dog bite (2.3%, 8) and unknown cause (0.6%, 2).

Time interval between trauma and presentation

The mean duration lapsed was 3.13±0.21 (Mean±SE) days for the animals presented during this study period. Majority of the cases (42.7%, 146 animals) were presented early (less than 2 days after injury), 30.1%, (103 animals) were delayed (2 to 4 days after injury), 18.4%, (63 animals) were presented late (8 to 9 days after injury) while 8.5%, (29 animals) were presented with excessive delay (beyond 8 days after injury).

Bone affected

In the present study, the number of femur fractures were highest (37.1%) followed by radius (30.2%), tibia (27.1%) and least in humerus (5.5%) as mentioned in Table-2

against each long bone region involved. Out of 363 number of long bone fractures, 337 were close and 26 fracture were compound in nature.

Unger's classification

Based on Unger's classification, highest number of fracture was of type 22A2 (15.7%) that represents distal diaphyseal radius-ulna fracture followed by 42A2 (9.9%) and 42A3 (8.8%) which represents simple oblique and simple transverse diaphyseal tibial fractures, respectively. Among femur fractures, transverse diaphyseal 32A3 (8.3%), oblique diaphyseal 32A2 (7.2%) and one reducible wedge 32B1 (6.9%) were recorded.

Evaluation of outcome and complications of treatment modality

Bone wise treatment modality employedduring the study is mentioned in Table-3. Among long bone fractures in 132 animals treated with external co-aptation, minor complications like splint induced wound (12), skin slough (2) and limb swelling (8) were observed. Major complications like valgus deformity, fracture disease, limb shortening and anatomical malformation were observed in 8 puppies below 2 months of age. Mutilation of modified RJ bandage, slipping of cast, POP wetting and loosening and fractional mal-alignment were common findings. Functional healing with satisfactory weight bearing at last follow up was observed in 96 dogs and follow up of 28 dogs was not available.

A total of 198 out of 228 cases treated surgically recovered successfully, surgical attempt in 12 cases was unsuccessful with no satisfactory functional outcome. Seven cases were re-operated among unsuccessful cases. It was not possible to figure out outcome in 16 animals due to lack of post operative follow up. Two dogs died due to reason unrelated. Immediate post operative radiographs of 211 cases had near perfect anatomical reduction and 17 animals had translational mal-alignment.

Out of 204 animals treated with internal fixation, minor complications (like skin dehiscence and pressure sores due to post operative Robert-Jones bandage application) were observed in 14 cases. Major complications observed in animals were like pin migration (4), mild arthrosis (2) and severe arthrosis (1) in the procedure of intra medullary/cross pinning. In 56 cases treated with LCP application screw loosening (3), plate bending (3), repetitive skin ulceration (2), osteomyelitis (1) and atropic non-union (1) were observed. Plate removal due to complications was done in 4 cases. In 9 cases plates were removed after complete clinical union. In rest of the cases plates were not removed either for economic constraints, some owners either did not opted and a few did not presented for a recheck. None of the animals had plate exposure and refracture after plate removal. Radial, femoral and tibial fracture in dogs treated with open reduction and locking compression plate fixation resulted in a successful fracture union and return to normal function at the last follow-up.

Out of 24 cases treated with External skeletal fixation, 23 recovered uneventfully with satisfactory radiographic and functional healing (Fig. 5 A, B &C). Pin tract infection and loosening were main minor complications of ESF recorded in dogs. Iatrogenic fracture of the bone through fixation holes a major complication was recorded in one case.

TABLE3: Bone wise treatment modality employedduring the study

Treatment modality/Bone	Humerus	Radius & Ulna	Femur	Tibia	TOTAL
External co-aptation	10	79	12	31	132
Rush pin			1		1
Cross pin			18		18
IMP	9		48	50	107
ILN			15		15
Locking compression plating		12	39	5	56
ESF		16		8	24
Tension Band wiring		1		3	4
Lag screw fixation			3		3
Amputation		1		2	3
TOTAL	19	109	136	99	363

FIGURE 1A: An oblique diaphyseal fracture of tibia. B: Internal fixation with intramedullary pin one month after surgery showing callus formation.

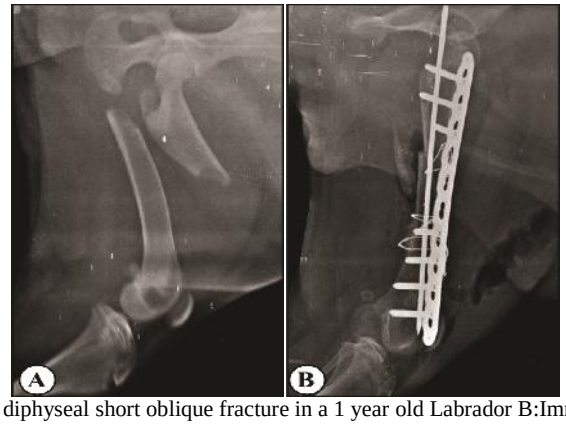

FIGURE 2A: ML view of proximal diphyseal short oblique fracture in a 1 year old Labrador B:Immediate post operative radiograph of Plate rod construct using a 3.5mm locking compression plate and 3.5mm intramedullary rod

FIGURE 3A: 3.5mm locking compression plate and circlage wiring for mid diaphyseal fracture of tibia after one month post surgery

FIGURE 4: ML view of femoral distal diaphyseal fracture treated with interlocking nail 60 days after operation showing radiographic healing

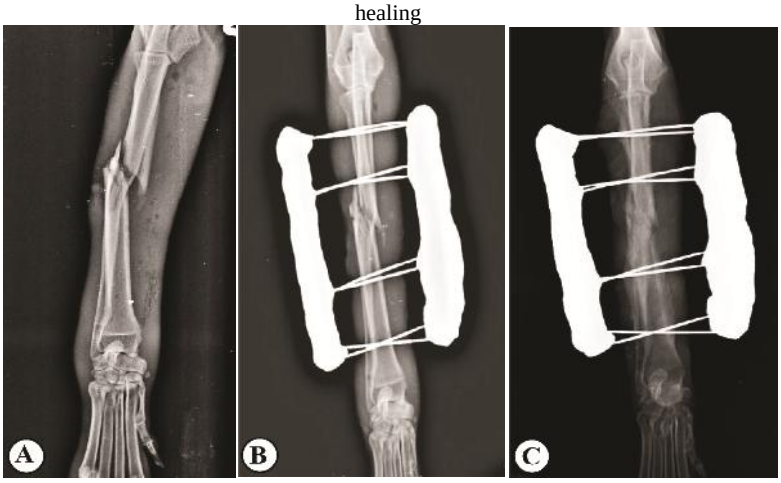

FIGURE 5A: AP view of open radius and ulna fracture in a 10 month old ND dog. B: Same case treated with bilateral biplanar ESF with epoxy putty used connecting bars. C: one month post operative showing callus formation

DISCUSSION

Fracture fixation in animals either external or internal is a very challenging. Different modalities of internal fixation has been tested and tried in animals. In the present study, total of 362 canine long bone fracture cases were recorded during the period from July 2017 to Dec 2018. Previously Kallianpur *et al.* (2018) recorded 216 cases over a period of one year and Kumar *et al.* (2013) recorded 691 cases over a period of six years in the same locality. Hence increase in pet population, increase in vehicle traffic, referral nature of hospital and owners being aware of veterinary services available have led to the increase in number of fracture cases presented to hospital.

Occurrence of fracture in non-descript dogs was highest in the present study which may be due to relatively higher population of ND dogs and their free roaming habit making them more vulnerable to road traffic accidents (Kumar et al., 2013). Occurrence in other breeds of dogs may be indicative of companion animal culture of the locality.

Young puppies of 1-6 months were most affected followed by age group of 6-12 months. The highest incidence rate in young puppies can be related to their active, playful nature and inabililty to cope with the risks of environment (Kolata *et al.,* 1974). Several earlier reports also show a higher incidence of fractures in young dogs (Aithal *et al.*, 1999; Kumar *et al.,* 2013). Male animals were found to be more affected than female animals in the present study. Higher incidence in male animals might be due to aggressive nature and wandering habits of the male dogs which make them more prone to accidents and fractures as reported by Kolata et al. (1974). Majority of the patients were intact male and females. There was no significant relationship of gender with other parameters hypothesized.

Road traffic accident was the most common cause of canine fractures followed by fall from height. Similarly, Ali (2013) found road traffic accidents followed by indoor traumas as most common forms of trauma causing fractures. Similarly, fall from height was also reported to be a major cause of fracture in dogs (Kallianpur et al. 2018). Free and wandering habit of dogs and increasing vehicle traffic may be attributed for the cause of fractures. Also multilevel housing culture and pets encountering fall from height either playfully or due to sudden panic like burst of crackers etc. may be attributed to such incidence.In the present study, 42.7% of the cases were presented in less than 2 days after injury which indicates prompt response by the clients and animal lovers. But the mean time duration lapse was above 3 days between trauma and presentation. Late presentation of cases can be attributed to referral nature of the polyclinic and arrival of cases from distant locations. Also late presented cases had open fractures below the elbow and stifle joints and had significant soft tissue damage. Dvorak et al. (2000) found complications in fracture healing with interval between injury and fracture fixation longer than 4 days. However, no such significant association between time lapse and outcome was found in the present study. Similar findings were found by Kallianpur et al. (2018).

Femur followed by radius-ulna, tibia-fibula were the most commonly affected long bone fracture, where as humerus was the least affected bone. Similar results were found by Kumar et al. (2013) and Kallianpur et al. (2018) from their studies at the same place. Ali (2013) opined that as canines expose their hind quarters to major force of impact leads to higher incidence of hind limb fractures than fore limb fractures.

In the present study 22A2 (distal diaphyseal radius-ulna) followed by 42A2 (simple oblique diaphyseal tibia), 42A3 (simple transverse diaphyseal tibia) and 32A3 (transverse diaphyseal femur) were the most encountered types of fractures according to Unger's classification. Similarly type 22A2 was found to be the most common type of fracture along with types 32A3, 32A2, 42A3 and 42A2 as reported by Kallianpur et al. (2018). Whereas Libardoni et al. (2016) found type 33A1 as the most common type of femoral fracture encountered.

Fracture fixation methods and complications

In the present study, among 132 dogs treated by external co-aptation, functional healing and satisfactory weight bearing and gait was observed in majority of cases with some minor complications. Indications for external coaptation include close fracture below elbow and stifle, fractures in which bones remain stable after reduction (type A and B fractures), greenstick fractures, fractures in young animals where periosteal sleeve is mostly intact and impaction fractures (Piermattei *et al.*, 2006). It was found that young dogs had good prognosis with R-J bandage and casts for fractures below the elbow and stifle joints. Comminuted fractures and unstable oblique and spiral fractures were avoided for external coaptation. It was also found that Schroeder-Thomas splint can be used as effective traction devise to treat stable humeral and femoral fractures in young dogs.

Intramedullary pinning was most preferred method of internal fracture fixation in young animals with simple transverse and short oblique diaphyseal fractures with satisfactory results in majority of cases. Piermattei et al. (2006) also opined intramedullary pining is preferred method of fixation in stable fractures that do not have tendency for axial shortening or rotation, primarily type A fractures, type B and some type C fractures in skeletally immature animals especially in puppies less than 4 months of age with rapid callus formation. Pin migration was encountered in 4 animals which can be attributed to factors like improper seating of pin into the distal condyle due to spiral nature of humerus, cranial bowing of femur shaft, improper selection of the size of the pin and lack of owner compliance in maintaining post operative movement restriction especially in aggressive animals.

Proper seating of intramedullary pin into the distal metaphysis was a common technical problem encountered in dogs with femoral fractures. The problem was solved by angling of fracture fragments slightly caudally during pin insertion. Most dogs have pronounced cranial bowing of the femoral shaft and seating of the intramedullary pin into the distal fragment of the bone may be a problem and pin may penetrate the cranial cortex just proximal to the femoral trochlea. Piermattei et al. (2006) opined that angling of both segments slightly caudally just before insertion of the intramedullary pin into the distal fragment which allows deeper insertion of the pin in the cancellous bone of the distal metaphysis which greatly improves stability.

Mahajan et al. (2007) comparatively studied different fixation methods for SCF of femur in dogs and opined that cross pinning and with intramedullary pinning provides rigid fixation and stable reduction of SCF compared to retrograde intramedullary pinning and oblique pinning. Whereas, Singh et al. (2011) compared modified T plate and cross pinning methods for the fixation of SCF in dogs and opined that modified T plate was better technique and provides rigid fixation and stabilization with less post operative complications in spite of technical difficulty to perform, causing more trauma and being time consuming. Cross intramedullary pinning was most preferred method for the fixation of SCF in the present study owing to its familiarity and accustomed procedure.

In the present study, LCP alone and LCP as a plate rod construct was found to be more stable fixation method, less time consuming, provided immediate post operative weight bearing and early functional recovery in most of the cases. Sarangabani et al. (2017) evaluated plate-rod technique for treatment of diaphyseal tibial fractures in dog using 3.5mm LCP and 1-2mm K wire and opined that plate-rod technique provided rapid healing and early callus formation. Sarangom et al. (2018) in a previous study opined that plate-rod construct can be used for the repair of diaphyseal femoral fractures of young dogs with wide range of severity by placing bone plates away from the epiphyseal growth plates. Similar technique was applied in the present study and usage of LCP as plate-rod constructs provided satisfactory implant stability, early post operative weight bearing and radiographic bone healing in fixation of unstable femoral fractures. Schwant (2005) opined that in order to avoid complications in LCP, additional placement of rod appears to be necessary in comminuted fractures.

Although the locking screws allow the plate to be placed completely away from the periosteal surface, the true extent of the plate contact with the bone is likely variable. In clinical cases, the plate is frequently in contact with the bone even if it is not compressed against it (Moens, 2019). Screws and bone plates are equally guilty of impairing blood supply to the cortex because screws impair medullary blood supply and plate may impede blood flow to the portion of cortex immediately under the plate (Sumner-Smith, 1991). Atropic non-union encountered in one case may be due to rigid internal fixation and excessive load sharing of the implant.

Haaland et al. (2009) evaluated LCP for appendicular fracture repair in 47 canine cases and opined that via a less invasive approach LCP can be successfully used for the treatment of long bone fractures in dogs. It combines mechanical advantages of internal plating techniques with minimal soft tissue surgical trauma of external fixator. LCP allows controlled flexibility to facilitate secondary bone healing. Gilbert et al. (2015) used LCP as a hybrid construct for the treatment of distal radial and ulnar fractures in toy and miniature breeds of dogs and found excellent clinical results with uncomplicated healing and functional outcome. Similar use of LCPs in fixation of radial and tibial fractures in present study lead to excellent and early postoperative weight bearing.

Use of ILNs in treatment of unstable diaphyseal femoral fractures resulted in excellent clinical outcome. It was advantageous and preferred method of fixation in non reducible wedge and segmented fractures in the present study. Arican et al. (2017) clinically evaluated interlocking nails in dogs and opined that use of ILNs to repair diaphyseal femur, tibia and humeral fractures in dogs resulted in a good or excellent functional outcome in most patients.

In the present study 2mm and 2.5mm smooth trocar pointed K-wires and epoxy putty connecting bars were found strong in maintaining the stability of the construct and ensured immobilization of the fracture. The freeform external skeletal fixator using acrylic as a replacement for a metallic bar may be useful to treat bone fractures and luxations in small animals, as it is mechanically strong, lightweight, economical, and pins can be passed from any direction depending upon the clinical situation (Tyagi, 2015). External skeletal fixation has proven to be successful in the treatment of fractures of distal radius and ulna, although specific post operative management and frequent follow up examinations require substantial owner compliance (Piras *et al.,* 2011). Fixator-associated complications are common in dogs, with the majority of complications related to pin tract infection (Beever *et al.,* 2018). However, regular post operative dressing and care and owner compliance is required for external skeletal fixation. In one case of iatrogenic fracture through the fixation holes it was found that the dog was extremely aggressive with high muscular activity and owner could not confine the dog or restrict the movement.

CONCLUSION

The study demonstrated that intramedullary pinning when properly applied is effective in treatment of simple and stable diaphyseal fractures and in combination with ancillary devices like wiring for long oblique, type A and B1 fractures of humerus, femur and tibia in puppies and medium sized dogs. Cross intramedullary pinning in SCF of femur was found to be a good option of fixation. Locking compression plating was found to be advantageous to achieve desired implant stability to overcome shortcomings of pining and suitable size of implant and screw configuration must be preferred according to the age, breed, body weight, temperament and muscular activity of the dog. Also interlocking nail system is desirable for wedge and segmented diaphyseal fractures of femur and requires familiarity with equipment and experience. However, the selection of type of internal fixation method may vary widely with each case and is purely based on suitability of the technique and type of fracture. Locking compression plating gives rigid stability and early return to full function in long bone diaphyseal complex fractures in dogs. In large size dogs, working and sporting breeds and dogs with high level of muscular activity bridging osteosynthesis with plate-rod method can be applied to achieve desirable level of stability and healing especially in femur which is subjected to eccentric loading. Bilateral biplanar modified external skeletal fixation of open fractures of radius-ulna and tibia with radiographic, clinical data and preoperative planning resulted in successful fracture union.

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