

Retrospective Study on Canine Femoral Fractures: Incidence and Surgical Management

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ABSTRACT

The present study is carried out to record the incidence of femoral fractures among different breeds of dogs, as well as to evaluate different fixation techniques recommended by variant teaching hospitals and private clinics in Egypt. This study was conducted on 654 clinical cases of both genders and different breeds suffering from different femoral fractures which were referred to some teaching hospitals and private pet clinics in Egypt over a period of 5 years. The obtained data regarding animal's age, breed, weight, treatment technique, minor and major complications were analyzed statistically based on client observations survey, clinical records, survey, and sequential follow-up radiographs. Femoral fracture accounts to be 44% of all canine long bone fractures. The diaphysis is mostly affected (64.9%) compared to other parts of the bone as well as, transverse and oblique fractures were reported to be 86.5%. Transverse, oblique, and comminuted diaphyseal femoral fractured were managed successfully using a plate-rod technique (71.4%), IMP alone (79%) or in combination with cerclage wire (77%) respectively. All cases were treated with interlocking nails (ILNs) and showed complete healing without complications. On the other hand, cross pinning fixation was the best for the management of distal femoral fractures with a 77.8% success rate.

Keywords: Bone, Dog, Femoral fracture, Fixation.

INTRODUCTION

In recent years, the interest in raising pets has increased, and the purposes of keeping them have varied including beauty, guarding, racing, and hunting which made them vulnerable to various injuries. Canine long bone fracture is one of the most important of them which constitutes a major problem encountered by dog owners (Gadallah et al., 2009). Animal's age, breed, sex, weight, and nature of the work plays an important role in determining characteristics and nature of long bone fracture (Simon et al., 2011; Ayyappan et al., 2011; Kallianpur et al., 2018; Abo-Solima et al., 2020).

The incidence of bone fractures in dogs was found predominantly in hind limbs compared to

the fore ones (Jain et al., 2018; Abo-Soliman et al., 2020). Brinker et al., (2006) previously stated that it is interesting to speculate why almost 3 of every 4 long bone fractures in small animals occur in the hind limb. Fracture of the femur was reported to be the most common skeletal condition affecting growing dogs (Tercanliogu, and Sarierler, 2009). It was reported to be 20% of all fractures and 45- 47% of all long bone fractures (DeCamp et al., 2016). It was also reported that femoral fractures constitute the most predominant form occurred at or below 2 years of age (Braden et al., 1995). It usually occurs as a result of violent trauma with a vehicular accident, gunshot injuries, and falls or occasionally due to pathologic diseases

because of primary or metastatic bone tumors. It can result in both life-threatening injuries, severe and permanent disability (Gadallah et al., 2009; Fossum et al., 2013; Jain et al., 2018)

Among different breeds of dogs, femoral fractures commonly occur in German shepherds (85%), Doberman pinscher (5%), and White Griffon (5%) (Abd El Raouf et al., 2017). It occurs mostly at the proximal or distal physis in immature dogs while in mature animals metaphyseal and diaphyseal fractures are the most frequently recorded. It can be categorized in form of capital physeal, femoral neck, trochanteric, subtrochanteric, diaphyseal, supracondylar, condylar, or distal physeal fracture. In most of the recorded cases skin remains intact because of the heavy overlying muscles, except in cases of a penetrating injury as in the case of gunshot wounds (Beale 2004; Tobias and Johnston, 2012; Fossum 2013; Abd El Raouf et al., 2017).

Femur fractures in dogs can be managed by a variety of surgical techniques. Each of them has its own advantages and disadvantages. They are not amenable to conservative treatment, and internal fixation is required. Most of the recommended techniques for the repair of femoral fractures aiming to promote fracture stability with a significant reduction in the local strain at the fracture site (El-Husseiny et al., 2012). It includes intramedullary pinning alone or in combination with cerclage wiring (Howard 1991; Hulse, and Aron, 1994; Aron et al., 1995; Muir, and Johnson, 1996), external skeletal fixation (Farag et al., 2001), tie-in (Gadallah et al., 2009), cross pin, bone plates, interlocking nail (ILN), and plate-rod techniques (Lovrić et al., 2020; Wangchuk et al., 2021). The present study aims to record the incidence of femoral fractures among different breeds of dogs, as well as to evaluate the efficacy of different fixation techniques recommended by variant teaching hospitals and private clinics in Egypt.

MATERIAL AND METHODS

The present study was carried out in cooperation between the referral veterinary

teaching hospitals at the university of Sadat city and Cairo university. The study protocol followed the regulation of the Institutional Animal Care and Use Committee (IACUC), Faculty of Veterinary Medicine, University of Sadat City, Egypt. A survey study was carried out on a total number of 654 dogs (from 2 months till 13 years old) of both sexes and different breeds which were referred for diagnosis and management of different long bone fractures at the teaching veterinary hospital of the faculty of Veterinary Medicine University of Sadat City, Radiology Unit of referral veterinary teaching hospital, Faculty of Veterinary Medicine, Cairo University, and some private pet clinics at Cairo, Giza, Gharbia, Alexandria, Dakahlia, and Qalyubia governorates during the period from January 2017 to January 2022.

The obtained data regarding animal's age, breed, weight, treatment technique, minor and major complications were analyzed statistically based on client observations survey, clinical records, survey, and sequential follow-up radiographs. The chosen modality and technique for fixation used for each case were recorded (Minar et al., 2013; Bennour et al., 2014).

RESULTS

Long bones fracture recorded in this study were distributed as following out of 654-case 288 (44%) cases suffered from femoral fracture, 148 (22.6%) cases suffered from radius and ulnar fracture, 145 (22.2%) cases suffered from tibia and fibula fracture, and finally, 73 (11.2%) cases suffered from humeral fracture. The femoral diaphysis is the most affected part followed by the distal extremity and finally the proximal extremity (Table 1, Fig. 1&2). Fracture line characteristics reported in this study were simple (transverse, oblique, or spiral) or comminuted (Table 2, Fig. 1&2). The transverse shape of the fracture line showed the highest rate of incidence, followed by the oblique, then the comminuted, and finally the spiral.

Table (1): Showing percent of fracture distribution among different parts of the femur:

Bone	Femur			Total
Affected part	Proximal	Diaphyseal	Distal	
Number	14	187	87	288
Percent %	4.9 %	64.9 %	30.2 %	100 %

Table (2): Showing distribution of fracture line characteristics in relation to the longitudinal axis of the femur:

Bone	Femur				Total
Shape of fracture line	Single			Comminuted	
	Transverse	Oblique	Spiral		
Number	167	82	6	33	288
Percent	58 %	28.5 %	2 %	11.5 %	100 %

According to this study, different breeds of dog were recorded to be affected with a femoral fracture are the mongrel (mixed breed) dog (99/288 with 34%), followed by German shepherd (67/288 with 23.3%), Brussel griffon (27/288 with 9.4%), Pomeranian (23/288 with 8%), Chihuahua (17/288 with 6%), Golden Retriever (10/288 with 3.5%), American Pit-bull (7/288 with 2.4%), German Rottweiler (6/288 with 2%), Alaskan Husky (6/288 with 2%), Dalmatian (6/288 with 2%), Great dan (6/288 with 2%), Caucasian (3/288 with 1%), French bulldog(2/288 with 0.7%), Boxer (2/288 with 0.7%), Genoa (2/288 with 0.7%), Maltese (2/288 with 0.7%), Belgian Malinois (2/288 with 0.7%), and Beagle (1/288 with 0.3%). Also, dogs below one-year-old showed a high percent of femoral fracture (57%) compared to older ones.

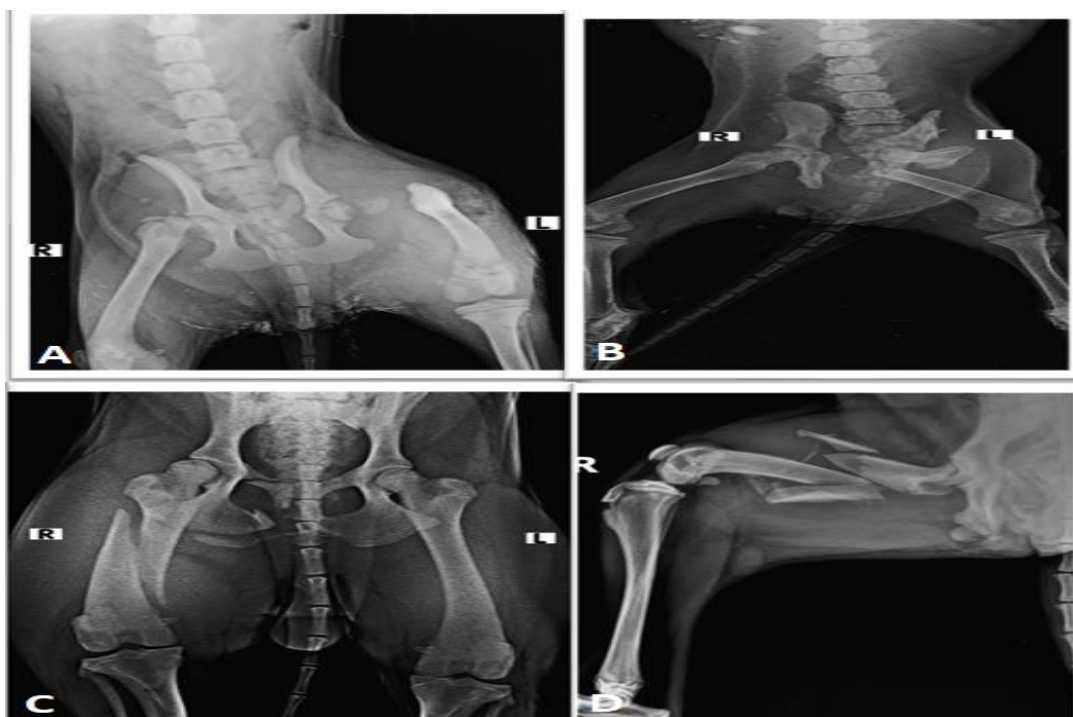


Figure (1):
A: Ventro-dorsal radiographs of the left femur of a seven-month-old male mixed breed dog showing transverse fracture at the neck of the femur.

B: Ventro-dorsal radiographs of the left femur of a six-month-old male mixed breed dog showing transverse diaphyseal fracture at the proximal third of the femoral shaft.

C: Ventro-dorsal radiographs of the right femur of a 1.5 years-old male German shepherd dog showing long oblique diaphyseal femoral fracture.

D: Medio-lateral radiographs of the right femur of a one years-old female mixed breed dog showing comminuted diaphyseal femoral fracture.

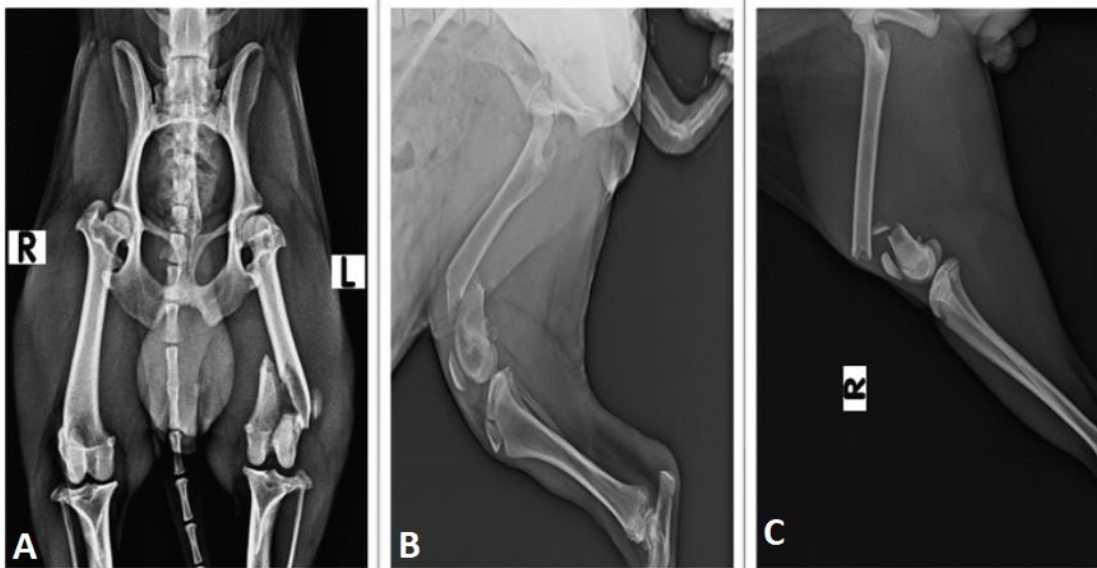


Figure (2):

A: Ventro-dorsal radiographs of the left femur of a two-year-old male griffon dog showing Salter-Harris type IV fracture of the distal femur.

B: Medio-lateral radiographs of the right femur of a one years-old male German shepherd dog showing transverse diaphyseal fracture of the distal third of femoral shaft (supracondylar fracture).

C: Medio-lateral radiographs of the right femur of a one years-old male Pomeranian dog showing transverse diaphyseal fracture of the distal third of femoral shaft (supracondylar fracture).

Out of the total reported cases of femoral fracture (288 cases) in this study, 111 cases were subjected to complete examination and follow-up evaluation. These animals were managed using different fixation techniques including external fixation (4 cases, 3.6%), Intramedullary pinning (IMP) (61 cases, 54.9%) (Fig. 3A), plate-rod technique (BP+IMP) (7 cases, 6.3%) (Fig. 3B), bone plate (BP) (15 cases, 13.5%) (Fig. 3C), K-wire (23 cases, 20.7%) (Fig. 4A), and interlocking nails (ILNs) (1 case, 0.9%) (Fig. 4, B) (Table 3). Internal fixation techniques were mostly selected for the management of femoral fracture compared to external fixation one. Intramedullary pinning (IMP) had been selected for the management of 46.7% (25.2% of the total), 73.5% (22.5% of the total), and 47% (7.2% of the total), of the referred cases suffered from transverse, oblique, and comminuted fractures respectively. Cross pin technique had been selected for the management of 35% (18.9% of the total), 3%

(0.9% of the total), and 5.9% (0.9% of the total) of the referred transverse, oblique, and comminuted fractures respectively. Bone plate technique had been selected for the management of 11.7% (6.3% of the total), 14.7% (4.5% of the total), and 17.6% (2.7% of the total) of the referred transverse, oblique, and comminuted fractures respectively. Plate-rod technique has been selected for the management of 1.7% (0.9% of the total), 8.8% (2.7% of the total), and 17.6% (2.7% of the total) of the referred transverse, oblique, and comminuted fractures respectively. The interlocking nail technique had been selected for the management of only one case (0.9 % of the total), of comminuted fracture. External fixation technique has been selected for the management of 2.7 % of the referred transverse diaphyseal femoral fracture, and 0.9 % of the referred comminuted fractures respectively (Table 3).

Out of the 111 completely evaluated cases in this study, 77%, 78.3%, 71.4%, and

46.7% treated using IMP, K-wire technique, plate-rod techniques, and bone plate respectively showed healing without complication (Fig. 5A, B, C, &D). Only one case was managed using interlocking nail in this study (Fig. 4 B) which showed good healing without complication. On the other hand, most of the treated cases (75%) using external fixation showed complicated healing. According

to this study, the most recorded complication of healing is implant failure because of pin migration, screw loosening, and plate bending (in the case of bone plating) (Fig. 6A, B, and C). Other complications include improper healing such as non-union (Fig. 6A &D), malunion (Fig. 6B), and delayed union (Fig. 7A &B, Table 4, and chart 1).

Table (3): Showing selection of fixation technique according to affected part and shape of fracture line:

Affected bone	Femur							
	Affected part			Total	Shape of fracture line			Total
	Proximal	Diaphysis	Distal		Single		Comminuted	
Transverse				Oblique				
Intramedullary pin (IMP)	1 (0.9%)	54 (48.6%)	6 (5.4%)	61 (54.9%)	28 (25.2%)	25 (22.5%)	8 (7.2%)	61 (54.9%)
Cross pin (K-wire)	1 (0.9%)	3 (2.7%)	19 (17.1%)	23 (20.7%)	21 (18.9%)	1 (0.9%)	1 (0.9%)	23 (20.7%)
Bone plate (BP)	–	12 (10.8%)	3 (2.7%)	15 (13.5%)	7 (6.3%)	5 (4.5%)	3 (2.7%)	15 (13.5%)
Plate-rod (BP+IMP)	–	7 (6.3%)	–	7 (6.3%)	1 (0.9%)	3 (2.7%)	3 (2.7%)	7 (6.3%)
External fixation	1 (0.9%)	1 (0.9%)	2 (1.8%)	4 (3.6%)	3 (2.7%)	0	1 (0.9%)	4 (3.6%)
Interlocking nail (ILNs)	–	1 (0.9%)	–	1 (0.9%)	0	0	1 (0.9%)	1 (0.9%)
Total	3 (2.7%)	79 (71.2%)	29 (26.1%)	111 (100%)	60 (54.1%)	34 (30.6%)	17 (15.3%)	111 (100%)

Table (4): Showing success and failure rates in relation to each selected fixation technique for management of canine femoral fracture:

Bone	Femur		Total
	Success rate	Failure rate	
Intramedullary pin (IMP)	47 (77%)	14 (23%)	61
Cross pinning	18 (78.3%)	5 (21.7%)	23
Bone plate (BP)	7 (46.7%)	8 (53.3%)	15
Plate-rod technique	5 (71.4%)	2 (28.6%)	7
Interlocking nail	1 (100%)	–	1
External fixation	1 (25%)	3 (75%)	4
Total (Number / Percent)	79 (71.2%)	32 (28.8%)	111

Chart (1): Showing success and failure rates in relation to each selected fixation technique for management of canine femoral fracture.

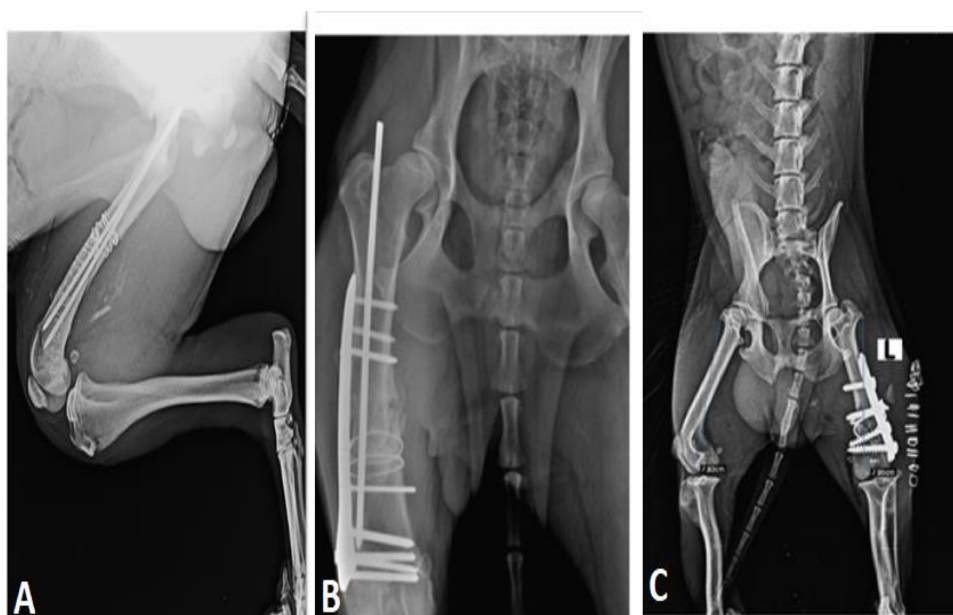
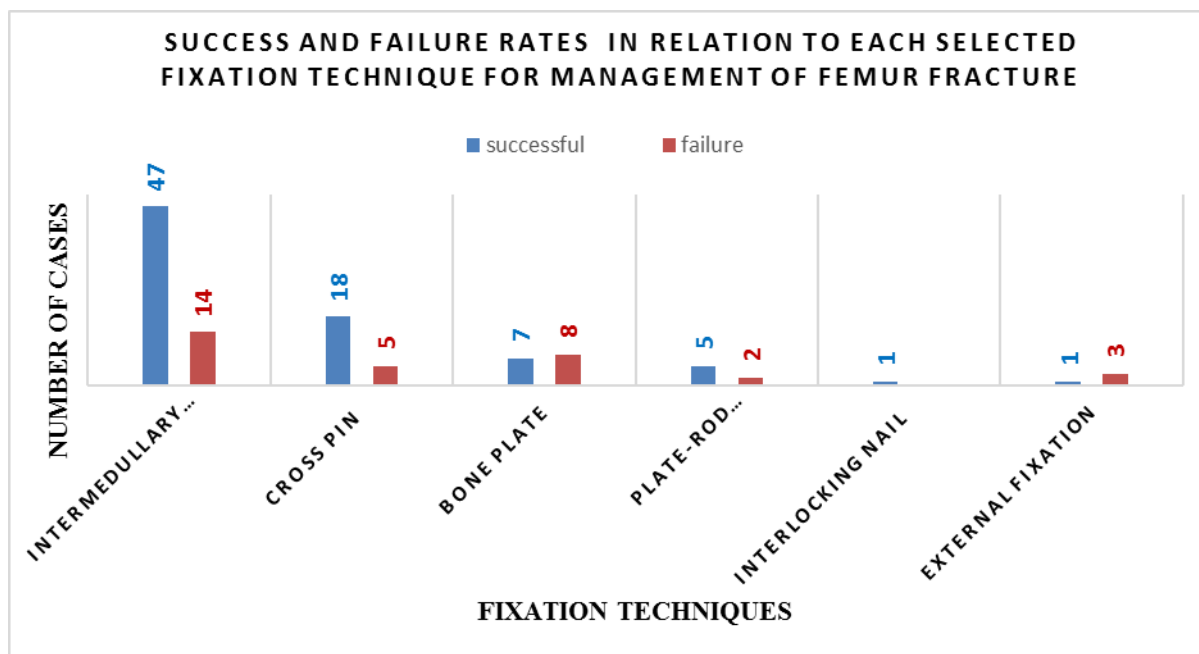


Figure (3):

A: Medio-lateral radiographs of the right femur of a 1.5 years-old male German shepherd dog showing oblique diaphyseal femoral fracture after management by intramedullary pinning combined with cerclage wire.

B: Ventro-dorsal radiographs of the right femur of a one-year-old female German shepherd dog showing comminuted diaphyseal femoral fracture after management by plate-rod technique (bone plate + intramedullary pin) combined with cerclage wire.

C: Ventro-dorsal radiographs of the left femur of a two-year-old male griffon dog showing oblique distal femoral fracture after application of bone plate combined with cerclage wire.

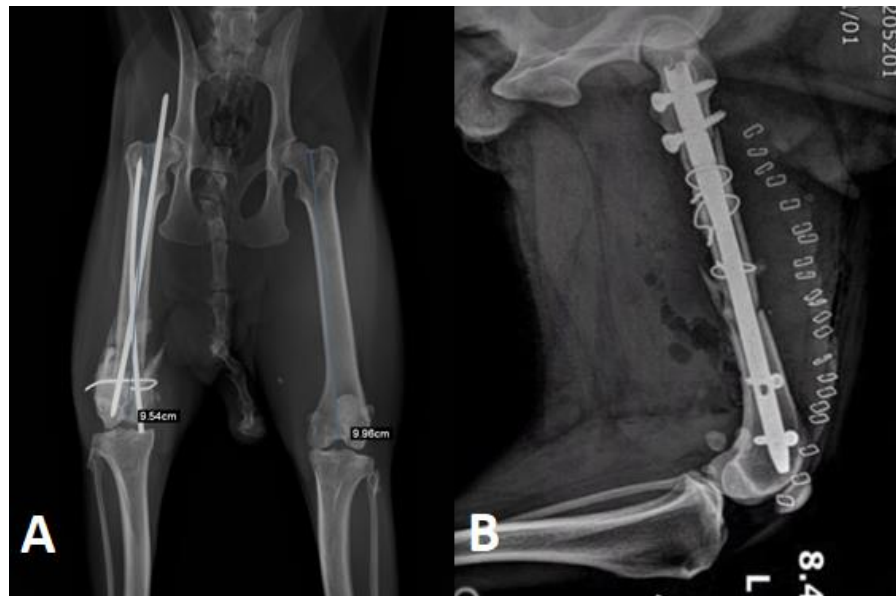


Figure (4):

A: Ventro-dorsal radiographs of the right femur of a two-year-old male griffon dog showing transverse distal femoral fracture after management by cross pin technique combined with cerclage wire.

B: Medio-lateral radiographs of the left femur of a two-year-old female dalmatian dog affected with comminuted diaphyseal femoral fracture after management by an interlocking nail (ILNs) combined with cerclage wire.

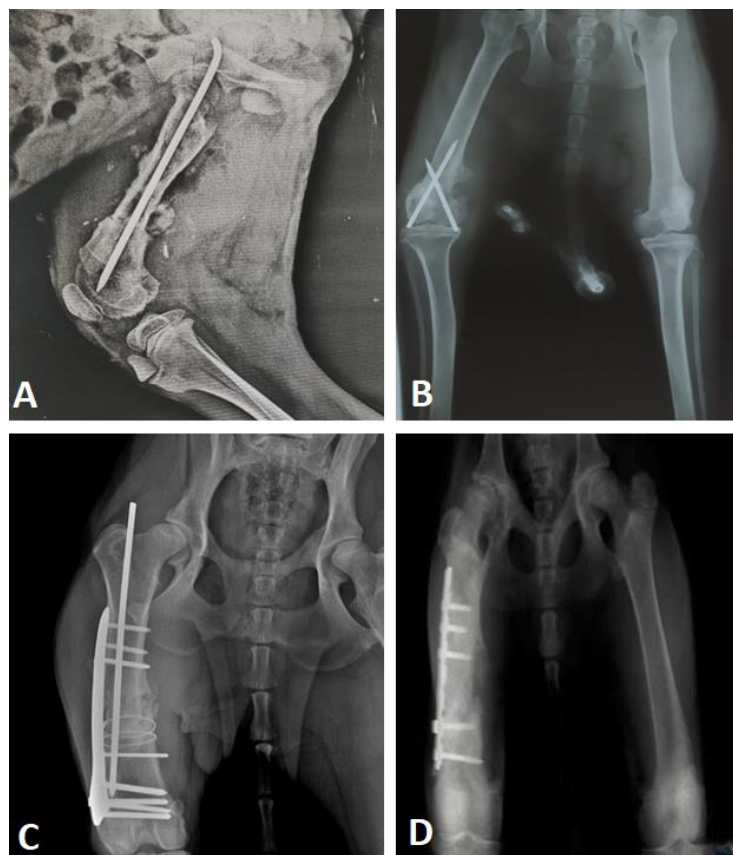


Figure (5): Showing successful management of femoral fractured using different fixation techniques.

A: Ventro-dorsal radiographs of the left femur of three months old golden retriever dog affected with transverse diaphyseal femoral fracture managed by intramedullary pin one-month post-operation.

B: Ventro-dorsal radiographs of a mixed breed male dog suffered from transverse distal femoral fracture managed by cross pinning three weeks post-operation.

C: Ventro-dorsal radiographs of the right femur of a one-year-old female German shepherd dog showing comminuted diaphyseal femoral fracture ten weeks after management by plate-rod technique combined with cerclage wire showing the progress of healing and disappearance of the fracture line.

D: Ventro-dorsal radiographs of the left femur of four-month-old male mixed breed dog showing complete transverse diaphyseal fracture managed by bone plate. six weeks post-operative.



Figure (6): Showing healing complications of femoral fracture repair using different techniques of internal fixation methods.

A: Medio-lateral radiographs of the left femur of a one-month-old German shepherd dog showing failure of intramedullary pinning.

B: Medio-lateral radiographs of the right femur of a three-year-old golden retriever dog showing malunion, implant (bone plate) failure, and loosening of screws.

C: Ventro-dorsal radiographs of right and left femur of one-year-old griffon dog showing implant (cross pin) failure (migration of pin) and complicated healing (non-union) (arrowhead).

D: Medio-lateral radiographs of the left distal femur of four months mongrel (mixed breed) dog treated with external fixation method showing improper fixation, and nonunion(white arrow)

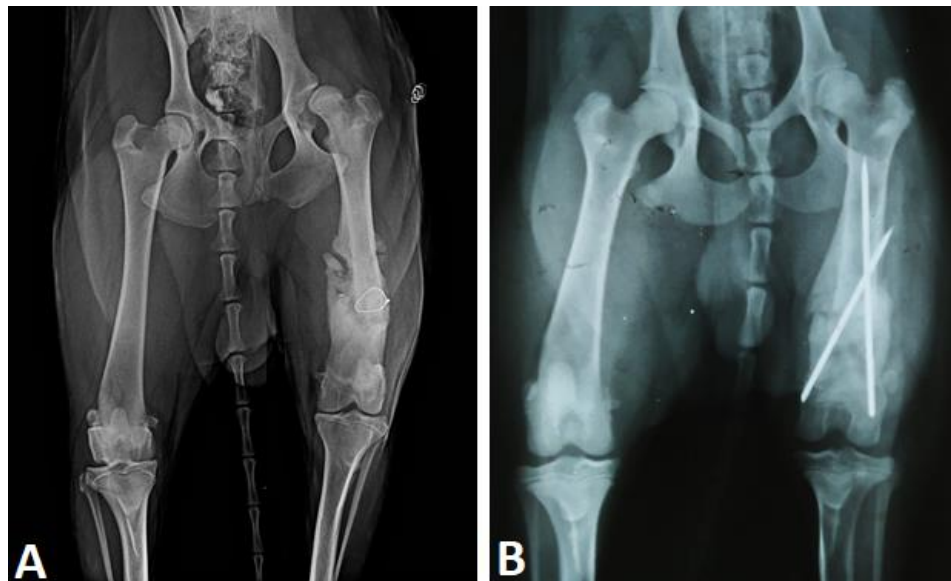


Figure (7): Showing healing complications of femoral fracture after management using different techniques of internal fixation methods.

A: Ventro-dorsal radiographs of the left femur of two-year-old German shepherd dog six weeks post-operative showing complicated healing (delayed union with abundant callus) after removing of intramedullary pinning combined with cerclage wiring

B: Ventro-dorsal radiographs of the left femur of an eight-month-old golden retriever dog two months post-operative showing complicated healing (mal-union), and implant failure after management using cross pin technique.

DISCUSSION

Dogs constitute most of the domestic pet population. Which makes it highly vulnerable to various injuries, especially bone fractures, that are frequently caused by traumatic injuries or bone pathology (Jain et al., 2018). The present study was carried out over a wide range of veterinary hospitals and clinics located in several governorates of Lower Egypt, over a period of five years to through the light on the incidence of long bone fracture between different breeds of dogs, as well as to evaluate variant fixation techniques used for management of femoral fracture.

According to this study, fracture of long bones of the hind limb showed a higher incidence rate (66.2%) compared to the fore ones (33.8). similar results have been recorded by Brinker et al., (2006). Harasen (2003) attributed this higher incidence rate to the animal's behavior while reacting with accident the conformation of dogs. He stated that the dogs were slow to react from their hindquarters when they were subjected to trauma such as automobile accidents therefore, the animal is mostly like to be hit from behind.

Fracture of the femur was recorded in this study to be the most compared to other long bones with an incidence rate up to 44%. Similar results have been reported by Minar et al., (2013), Elzomor et al., (2011), DeCamp et al., (2016) Jain et al., 2018; and Abo-Soliman et al., (2020). Furthermore, fractures at the femoral shaft showed a higher incidence rate (3 versus 1) compared to other parts of the bone. In addition, the occurrence rate of transverse/oblique fractures (54.1% & 30.6% respectively) were recorded to be higher compared to comminuted (15.3%) ones, these results were found in accordance with previous reports of (Tercanlioglu and Sarrierler, 2009; Shiju et al., 2011; Ben Ali, 2013; Abd El Raouf et al., 2017). We suggested that the anatomical characteristics of the femur and its inclined position within the animal's body make it liable to excessive stress more than other long bones other than the humerus. Which intern focuses the vertical forces (originating from the weight of the animal body and movement) on the long axis rather than the vertical axis of the bone.

Juvenile dogs below-one year showed a higher incidence rate (57%) compared to older ones. These results were found in accordance with

that previously published by (Braden et al., 1995 & 2009; Tercanlioglu and Sarierler, 2009) who attributed this to the activeness and, playfulness nature of the animals in this age which is not accustomed to cope with the risks of environment. Along with, in immature animals, the structural and biomechanical properties of bone are considerably different from those of adult ones which are characterized by lower yield stress and elastic modulus (Torzilli 1981; Aithal et al., 1999;).

Regarding the incidence of femoral fractures and their relationship to animal breed, the present study showed a variant pattern other than previous studies (Abd El Raouf et al., 2017; Kallianpur et al., 2018; Jain et al., 2018; Abo-Soliman et al., 2020). It can be stated that there is no consensual relationship between the dog breed and the incidence rate of femoral fracture. The rate of fracture occurrence between variant breeds may be influenced by the popularity of each breed in each particular locality (Ramesh 2011; Abd El Raouf et al., 2017).

Important factors in repair of the fractured femur include correct surgical approach, preservation of regional soft tissues and their attachments to bone fragments, adequate stabilization of the fractured fragments, appropriate choice, and application of the implant system, and proper postoperative care (Simpson and Lewis, 2003; Beale, 2004; Piermattei et al., 2006). The selection of the most suitable treatment technique was based on the direction of the fractured fragments, location of the fracture, whether open or closed, and joint involvement, available materials, and directives of the client, familiarity of the surgeon with fixation technique and equipment, animal age and size, and the number of involved limbs (Aron, 1998; Beale, 2004; Piermattei et al., 2006). Several techniques have been adopted to be used for the management of femoral fractures. According to this study, the external fixation technique has been used only for the treatment of 4 cases about 3.6 % of the total referred cases while techniques of internal fixation have been used for management of the rest of the cases (Beale, 2004; Lovrić et al., 2020). About 75% (three out of four) of the cases managed with external fixation showed poor outcomes. This can be attributed to the

anatomical position of the femur and the heavy musculature surrounding it which makes the femur not amenable to conservative treatment. Moreover, closed reduction is rarely possible due to adequate immobilization of the hip joint because of the close anatomical relationship to the abdominal flank and pelvis which interferes with the technique's ability to provide efficient stabilization of the fracture. From the aforementioned data, it can be stated that the external fixation technique is not recommended for the management of femoral fracture. In such a case open reduction with internal fixation is very essential for proper fracture repair of the femur (Simpson and Lewis 2003; Beale, 2004; Dueland et al., 2007).

According to the present study, IMP alone or in combination with other techniques such as cerclage wire was the most used technique (48.6%) for management of transverse, oblique, and comminuted fractures of the femoral shaft, followed by bone plating (10.8%), plate rod technique (6.3%), K-wire (2.7%), and finally interlocking nail (0.9%) (Lovrić et al., 2020; Wangchuk et al., 2021). Although IMPs provide an axial alignment and resist bending forces during weight-bearing, they are ineffective in neutralizing all destructive stresses such as shearing, compression, and rotation as well as it may delay functional use of the extremity. Previous reports advised its use in combination with other techniques. In the present study, it has been used in combination with cerclage wire and it was proven to be satisfactory with good results (Abd El Raouf, 2017; Popovitch et al., 2019). In other studies, IMP was used in combination with an external skeletal fixation for management of femoral fracture with good outcomes (Farak et al., 2001; Gadallah et al., 2009). It seems that the selection of IMP was attributed to its ease of application (limited open surgical approach), removal, and cost-effectiveness (Abou-El-Fetouh et al., 2015; Maritato & Rovesti, 2020).

According to this study, K-wire (cross pin) technique was mostly used for the management of transverse fractures at the distal extremity of the femur (17.1% of all treated cases and 65.5% of all fractures at femoral distal extremity). Furthermore, most of the treated cases showed healing without complications (78.3% success rate). These results agree with published data by

(Guiot et al., 2012). On the other hand, most cases treated using bone plate showed complicated healing (46.7% success versus 53.3 failure rates). These results were found inconsistent with (Şirin et al., 2013; Abd El Raouf et al., 2017) which reported that bone plates gave a satisfactory result in the management of femur fracture in medium and large size breeds. In the author's opinion, the higher failure rate in our study may be attributed to improper selection of plate size in relation to the weight of the affected dog or improper application of plate during surgery.

Comparing to the bone plating technique, most cases treated with the plate-rod technique showed good healing without complications (71.4 % success rate). In comminuted femoral fractures, the pin plate combination has proved to be a highly adaptable method of bridging osteosynthesis and proven more versatile because it combines both the advantageous aspects of intramedullary pinning and bone plating. In such technique, the IMP protects fractured bone from bending loads while the plate resists axial, torsional, shear, and compression forces. Moreover, the addition of an IMP to the bone plate reduces plate strain, increases bending strength twice, and fatigue life of the plate hundred-fold (Hulse et al., 1997; Reems et al., 2003; Beale, 2004; Vannini, 2004; Wangchuk et al., 2021).

In the present study, the interlocking nail has been recorded to be used for the management of only one case of comminuted diaphyseal fracture of the femur. In the authors' opinion, one case is not enough for evaluation of the technique, and further studies are required to evaluate the efficiency of the interlocking nail for management of femoral fracture in a dog.

Conclusion:

From the present study, it can be concluded that; the incidence of femoral fracture showed the highest rate between canine long bones. External fixation technique is not recommended for the management of femoral fracture. IMP in combination with cerclage wire is efficient for the management of femoral shaft fractures while cross pin technique is efficient for the management of fractures at the distal extremity of the femur. Plate-rod technique is preferred than bone plating for the management of comminuted fractures of the femoral shaft.

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