Research Article

Different Modalities of Metacarpal Fracture Fixation in Mongrel Dogs: An Experimental Study

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Abstract | The present study was conducted on 15 mongrel dogs as an experimental study on induced fractured metacarpal bones, which were divided into 3 groups, (n=5 each) as the following; group (1) fixation of III and IV metacarpal fractures using fiberglass, group (2) internal fixation using intramedullary pins and externally with fiberglass, group (3) internal fixation using bone plates. These animals were evaluated by the clinical examination and radiographic assessment for five months to evaluate the fracture healing. In group (1), degree of lameness noticed in all dogs and nonunion radiographically. In group (2) two dogs suffered from lameness due to nonunion of the fractured bones and migration of the pin to metacarpophalangeal joint and two dogs had the ability to walk and jump normally after two months, while in group (3), a dog suffered from lameness due to loosed screws and the others showed excellent healing. This experimental study revealed that the functional and anatomical results of dogs treated with internal fixation of metacarpal bones using bone plates were significantly better than those dogs treated with external coaptation and with intramedullary pins.

Keywords | Metacarpal, Fractures, Intramedullary, Plates, Fixation

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INTRODUCTION

Metacarpal and metatarsal fractures in dogs are reported to occur with an incidence of up to 11.9% of all fractures (Kulendra, 2014).

Metacarpal fractures are more common than that of metatarsal. Fractures occur commonly in more than one bone and mostly in the mid or distal regions of the metacarpus and the proximal region of the metatarsus. The fracture patterns are predominantly of a transverse and short oblique patterns (Tencer and Johnson, 1994; Muir and Norris, 1997; De La Puerta et al., 2008).

Metabones fractures are classified according to their anatomic location as fractures of the base, shaft and the head (Piermattei et al., 2006; Wernham and Roush, 2010).

Prognosis of metabones fractures is favorable with adequate reduction, alignment and fixation (Probst and Millis, 2003). Selecting the appropriate type of treatment depends on the fracture site (base, shaft, head), the number of affected bones, involvement of supporting bones, and the type of the patient activity. Metabone fractures can be treated in a conservative or a surgical manner (Wernham and Rouch, 2010; Seibert et al., 2011).

External coaptation (conservative treatment) has been recommended for minimally displaced fracture, fractures of one or two metacarpal or metatarsal (MC/MT) bones, where at least one of the two main weight bearing bones (III, IV) is intact (Manley, 1981; Muir and Norris, 1997; Kapatkin et al., 2000; Piermattei et al., 2006; Wernham and Rouch, 2010; Kornmayer et al., 2014). This fixation includes the use of casts, splints, bandages or slings to help stabilize fractures (Weinstein and Ralph, 2004).

Internal fixation (surgical treatment) has been recommended for fractures of more than two metabones, open fractures, severely displaced fractures, comminuted fractures, fractures of both weight bearing bones (III,IV), fractures involve the joint, fractures involve the middle or the distal metacarpal/metatarsal region causing great incidence of fracture displacement, fracture of II,V metabones with valgus and varus instability, and if the patient is large breed, working, athletic, or show dogs (Anderson et al., 1993; Muir and Norris 1997; Kapatkin et al., 2000; Probst and Millis 2003; Piermattei et al., 2006 and Wernham and Rouch 2010).

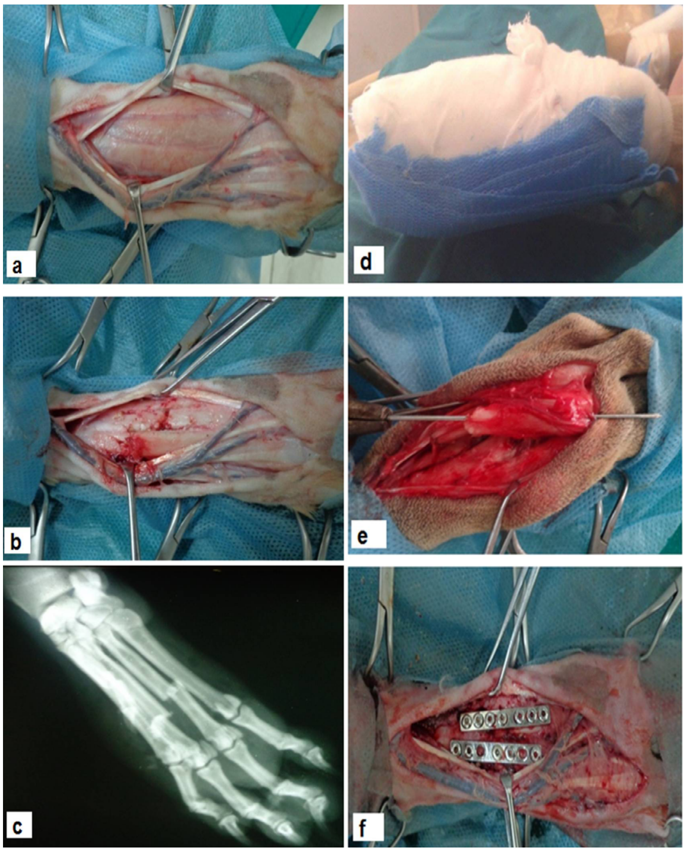

Figure 1: Showing the surgical steps of the fractured III and IV metacarpals and methods of fixations
a: showing extensor tendons were retracted laterally and medially exposing metacarpal bones; **b:** showing the fractured III and IV metacarpal bones at different levels; **c:** showing a representative x-ray film of the fractured III and IV metacarpals; **d:** showing application of fiberglass on the palmar aspect of the distal limb; **e:** showing application of K-wire (intramedullary pin) retrograde technique; **f:** showing application of bone plates (2mm).

Techniques of internal fixation in dogs include intramedullary (IM) pins, bone plates and screws, tension band wiring, and lag screws and percutaneous fixation (Earley and Dee 1980; Bellenger et al., 1981; Benedetti et al., 1986; Anderson et al., 1993; Gentry et al., 1993; Okumura et al., 2000; von Werthern and Bernasconi 2000; Dee 2005; Abd El-Khaleik 2010).

Kirschner wires (K-wires), Steinmann pins, and Rush pins can be used for intramedullary fixation of metabones transverse, and oblique diaphyseal fractures that not highly fragmented. IM pins often combined with cerclage wires in long oblique fractures (Piermattei et al., 2006).

Slotting technique is a method for intramedullary pinning of metabone fractures. This technique avoids the damage of articular cartilage and the interference of the motion of Metacarpophalangeal and metatarsophalangeal MCP/MTP joints (Anderson et al., 1993; Probst and Millis 2003; Dee 2005; Piermattei et al., 2006). Retrograde and slotting techniques are difficult in cats (Anderson et al., 1993).

Dowelling technique (Dowel pinning) is indicated for intramedullary fixation of metabones fractures in cats and toy breeds dogs. Soft tissue tension make distraction more difficult in the metatarsus than metacarpus and in proximal fractures compared with distal fractures (Zahn et al., 2006; Degasperi et al., 2007).

Small bone plates are valuable in large or athletic dogs, in comminuted, unstable, and non-union fractures. Both flat and semi tubular plates are used. Veterinary cuttable plates are very useful. They can be cut into desired length, easily contoured, have large number for screw holes, low price and their low profile minimize problems with tissues coverage during closure of the incision (Anderson et al., 1993; Piermattei et al., 2006).

Therefore, this study was performed to evaluate the fracture healing potential of various kinds of fixation for surgically created metacarpal fracture in a Mongrel dog model.

MATERIAL AND METHODS

The present study was conducted in Surgery, Anaesthesilogy and Radiology Department, Faculty of Veterinary Medicine, Zagazig University, Egypt on 15 Mongrel dogs as an experimental study for the evaluation of healing of induced metacarpal fractures after fixation with different methods. These animals were randomly divided into 3 groups, each group has 5 dogs as the following; group (1) fixation of III and IV metacarpal fractures using fiberglass, group (2) internal fixation of III and IV metacarpal fractures using intramedullary pins and externally with fiberglass, group (3) internal fixation of III and IV metacarpal fractures using bone plates.

These animals were evaluated by the clinical examination and radiographic assessment for five months to evaluate the fracture fixation after the healing period.

The Surgical Techniques

These animals were generally anesthetized using thiopental sodium® 2.5% (EIPICO) 20- 30 mg / kg B.wt. intravenous. The skin between the dorsal surfaces of III and IV metacarpals was incised, subcutaneous tissues were dissected exposing common digital veins. The extensor tendons were elevated and retracted medially and laterally to expose

Figure 2: Showing the radiographic examination after each method of fixation
a: showing fixation of the fractured III and IV metacarpals with external coaptation with fiberglass; **b:** showing fixation of the fractured III and IV metacarpals with intramedullary pins; **c:** showing fixation of the fractured III and IV metacarpals with Dynamic Compression Plate (DCP) (mini-plates).

the metacarpal bones (Figure 1a). The III and IV metacarpals were fractured at their diaphysis at different levels with bone cutter (Figure 1b and c). After proper reduction the fractured bones were fixed by using one of the following techniques:

Group 1

After the hemorrhage was controlled, the skin was sutured with non absorbable suture material (silk) and with simple interrupted suture pattern. The foot, carpus and the distal part of the forearm region were bandaged and fixed with molded fiberglass on the palmar aspect (Figure 1d) with good reduction of the fractured bones. Sterile and non adherent gauze pad was placed over the wound, with cotton padding between the toes and pads. The distal limb was wrapped with cotton (padding layer), which was fixed with elastic gauze, after, that the molded fiberglass was applied on the palmar aspect of the limb and fixed with another gauze layer. All the previous layers were fixed with wrapping of adhesive tape.

Group 2

The fractured bones were fixed with retrograde intramedullary bone pinning using K-wires (1.6mm) (Figure1e) as the following steps: The pin was inserted into distal fragment through the fracture line, the pin was advanced distally to penetrate the dorsal aspect of the head of the bone then the tip of k-wire was grasped till the proximal end of the pin disappears into the medullary canal after that the fragments were reduced, the blunt end of k-wire was inserted into proximal fragment and the distal end of the pin is bent and shortened. The same steps were applied on the other fractured bone. The distal limb was bandaged with application of fiberglass after wound closure as in group 1.

Group 3

The fractured bones were fixed with bone plates (Figure 1f) as the following steps: Reduction of the fractured bone. The selected bone plate (2mm) was applied and a hole was made using bone drill and bone bit (1.5 mm). Tapping and fixation of the screw (2mm) inside the hole by screw driver, firstly apply screws to the nearest two holes to the fracture line then proceed to the other holes alternatively. The same steps were applied on the other fractured bone. The distal limb was bandaged after wound closure.

After Care and follow up

X-ray was done using 65 Kv and 6.3 mA.s. exposure factors to confirm the good fixation of the fractured bone and confirm the good reduction (Figure 2a, b and c). The operated animals received a course of antibiotic and anti-inflammatory for 7 and 3 days, respectively. Also Calcium and Vitamin D source was supplemented for one month. The animals were housed in cages to reduce their activities and the bandages were checked twice daily. The wounds were dressed and the bandages were changed daily till the healing of the skin occurred. Ten days later the all skin sutures were removed. The fiberglass was applied for 8 weeks in group (1) and for 3 weeks in group (2). The animals were clinically examined daily for 5 months for evaluation of wounds healing and lameness. Radiographic assessment of the operated paw was performed every 2 weeks for 5 months.

Table 1: Clinical and radiographic examinations after using different modalities in metacarpal fracture fixation in dogs

	Group 1 (5 animals)		**Group 2 (4 animals)**		**Group 3 (4 animals)**	
	Number	%	Number	%	Number	%
Lameness	5	100%	2	50%	1	25%
Healing of the III & IV MC fractured bones	0	0	2	50%	3	75%
Nonunion of the III & IV MC fractured bones	5	100%	2	50%	1	25%

RESULTS

Clinical and radiographic examinations after using different modalities in metacarpal fracture fixation in dogs are recorded in Table 1 and demonstrated in Figure 6.

The clinical examination and radiographic follow up of the treated experimental animals revealed the following:

Group 1

1. The clinical examination: Two cases (40%) had skin lesions associated with the fiberglass after two months. All the dogs suffered from severe degree of lameness at all time.
2. Radiographic assessment: All dogs suffered from nonunion of the fractured bones (Figure 3a and b).

Group 2

1. Four from five cases continued to the end of the experiment
2. The clinical examination: Two dogs suffered from severe degree of lameness at all time. Two dogs had the ability to walk and jump normally after two months.
    - Radiographic assessment: A dog showed completes healing of the III metacarpal and nonunion of the IV metacarpal through 10 weeks (Figure 4a).
    - A dog showed nonunion of the III metacarpal and complete healing of the IV metacarpal through 15 weeks with bending of the pin (Figure 4b).
    - A dog showed complete healing of the III metacarpal and nonunion of the IV metacarpal through

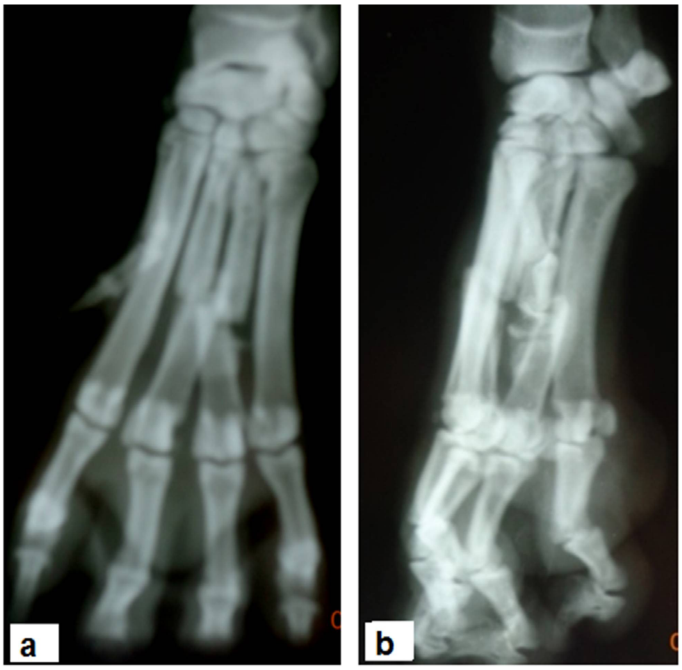

Figure 3: Showing nonunion in the III and IV metacarpal after eight weeks in group (1)
a: dorsopalmar view; **b:** latero medial view

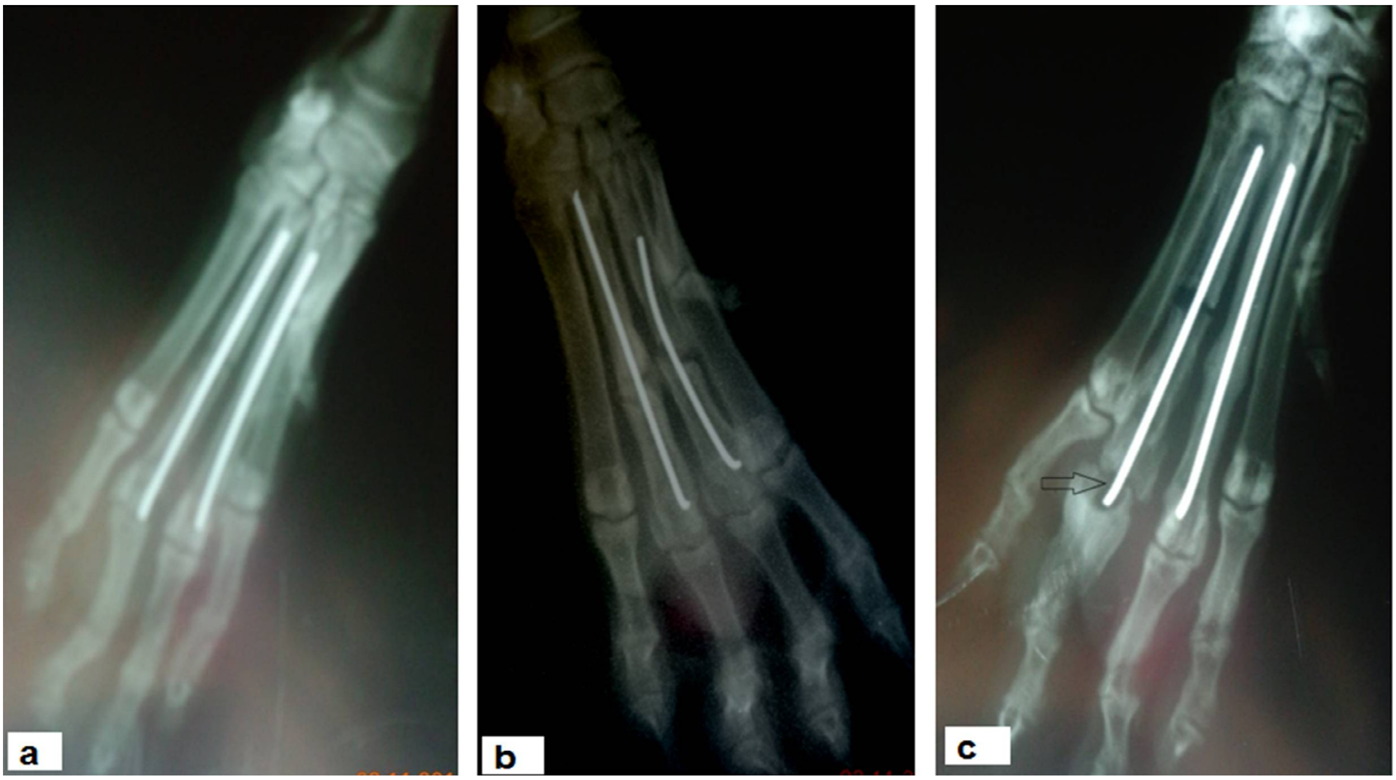

Figure 4: Showing the radiographic follow up in group (2)
a: complete healing of the III metacarpal and nonunion of the IV metacarpal within 10 weeks; **b:** nonunion of the III metacarpal and complete healing of the IV metacarpal within 15 weeks with bending of the pin; **c:** A dog showed complete healing of the III metacarpal and nonunion of the IV metacarpal within 12 weeks with migration of the pin to the metacarpophalangeal joint (arrow)

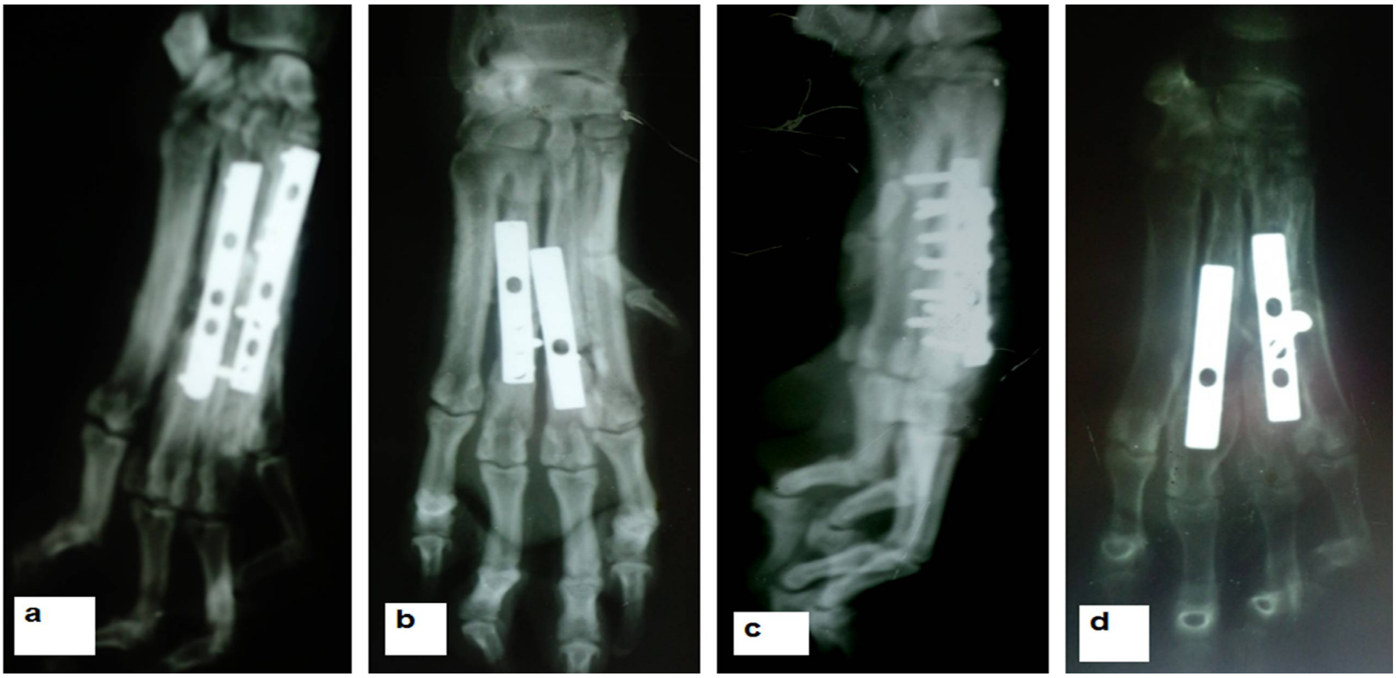

Figure 5: Showing the radiographic follow up in group (3)
a: healing of the fractured bone oblique view; **b:** dorsopalmar view; **c:** lateral view; **d:** loosed screw in the III metacarpal bone.

12 weeks with migration of the pin to the metacarpophalangeal joint (Figure 4c).

- A dog suffered from nonunion of the fractured bones (III and IV).

Group 3

Four from five cases continued to the end of the experiment.

1. The clinical examination: One dog showed palpation of loosed screws subcutaneously and suffered from severe degree of lameness at all time. Three dogs had the ability to walk and jump normally after one month.
2. Radiographic assessment: Three dogs showed complete healing of III and IV metacarpals within 16 and 18 weeks (Figure 5a, b, c). A dog suffered from nonunion in the III and IV metacarpals and osteomyelitis after four months with a loosed screw (Figure 5d).

DISCUSSION

Regarding the experimental study on 15 Mongrel dogs that were treated with different methods of fixation of metacarpal fractures, 13 were evaluated with clinical examination and radiographic examination for 5 months and 2 were lost to follow up.

It was demonstrated that the outcome of external fixation with fiberglass in the 1st group was unsatisfactory. All dogs suffered from severe degree of lameness at all time because of the nonunion of the fractured bones.

External coaptation did not maintain the correct alignment of the fractured bones during the healing period (Zahn et al., 2007) and it requires another method of fixation.

In contrast, the outcomes of internal fixation with IM pinning in the 2nd group and with bone plates in the 3rd group were satisfactory due to the correct alignment of the fractured III and IV metacarpals during the healing period.

In Group (2) where the fractured bones were fixed with intramedullary (IM) pinning and external fixation, retrograde pinning was used in our study, since it is easier and applicable method with low complications as reported by Wind (1976), Anderson et al. (1993) and Piermattei et al. (2006).

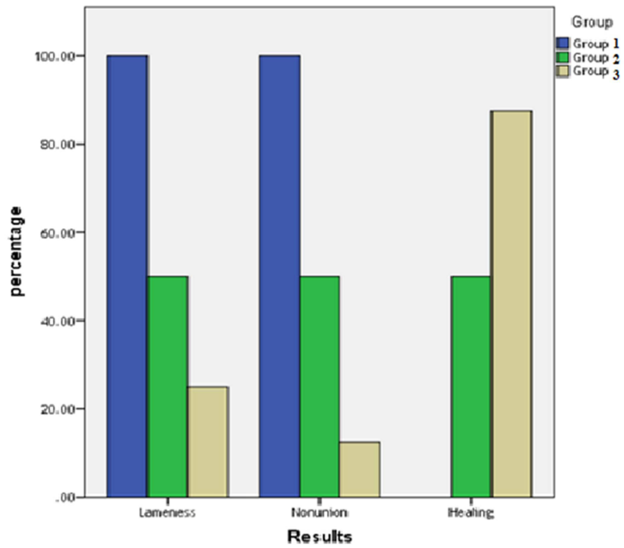

Figure 6: Chart illustrating clinical and radiographic examinations after using different modalities in metacarpal fracture fixation in dogs

Moreover, retrograde pinning avoided the technical difficulties associated with creating a slot in the dorsal aspect of the head (slotting technique) as mentioned by Fitzpatrick (2010) because there is a risk of splintering of the bone or bending of the K-wire during the introduction through the hole leading to malunion of the fracture (Zahn et al., 2007). Removal of all implants after the bone healing are advantages over dowelling technique (Degasperi et al., 2007; Zahn et al., 2007; Fitzpatrick 2010).

Metacarpal fractures couldn't be completely immobilized by using IM pinning alone and require additional support to minimize the risk of collapse or rotation, the fragment ends must be interdigitated and the pin must fill the whole length of the medullary canal with external coaptation for at least 3 weeks to improve the stability for the fracture. These were in agreement with Piermattei et al. (2006) and Zahn et al. (2007).

Two dogs suffered from severe degree of lameness and the others could walk and jump normally with good foot function in the 2nd group. Pain or lameness were due to osteomyelitis, which occurred in two cases due to abnormal wound healing and pin migration to metacarpophalangeal joint as reported with Zahn et al. (2007) and Fitzpatrick (2010).

In group (3) the fractured bones were fixed with bone plates. Application of bone plates was easily applied and fractures were efficiently reduced due to the presence of small amount of soft tissues covering the metacarpals (Piras and Guerrero, 2012).

The bone healing in group (3) occurred with high percent if compared with other groups as the plates achieved good reduction and good fixation during the healing period alone without external fixation as mentioned by Piermattei et al. (2006).

Open reduction and internal fixation of fractured metacarpals required long time for healing (10-15 weeks in IM pinning and 16-18 weeks in bone plate fixation). This was attributed to the paucity of periosteal soft tissues, which was in agreement with Kapatkin et al. (2000) and Seibert et al. (2011).

The functional and anatomical results in dogs treated with internal fixation were significantly better than those dogs treated with external coaptation. This was in agreement with previous reported studies of Muir and Norris (1997) and Zahn et al. (2007).

CONCLUSION

Internal fixation of metacarpal fracture in dogs with bone plates was better than intramedullary pinning. The complete healing occurred in group (3) with higher percent (75%) than in group (2) (50%), because IM pin act as an internal fixation but need an additional support, also they had serious complications such as irritation and injury of the metacarpophalangeal joint with the resultant residual lameness, bending of the pin and finally failure of the fracture reduction. These complications did not occur with the use of bone plates.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTION

Gomaa M and Youssef W carried out the surgical work and radiographic study. El Seddawy, F and Behery A planned and designed the study. All authors read and approved the final manuscript.

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