www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(12): 2401-2410

www.thepharmajournal.com
Received: 08-09-2023
Accepted: 12-10-2023

Ahemad K
MVSc Scholar Department of Veterinary Surgery & Radiology, College of Veterinary Science, Rajendranagar, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad, Telangana, India

Jagan Mohan Reddy K
Assistant Professor & Head, Department of Veterinary Surgery & Radiology, College of Veterinary Science, Korutla, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad, Telangana, India

Chandrasekhar EL
Professor & Univ. Head, Department of Veterinary Surgery & Radiology, College of Veterinary Science, Rajendranagar, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad, Telangana, India

Rajendranath N
Professor & Head, Department of Veterinary Anatomy, College of Veterinary Anatomy, College of Veterinary Science, Rajendranagar, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author:
Ahemad K
MVSc Scholar Department of Veterinary Surgery & Radiology, College of Veterinary Science, Rajendranagar, P.V. Narsimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad, Telangana, India

A clinical study on the use of polyaxial locking plate system in the treatment of long bone fractures in dogs

Ahemad K, Jagan Mohan Reddy K, Chandrasekhar EL and Rajendranath N

Abstract
The present clinical study was conducted on 6 dogs with long bone fractures using Polyaxial Locking plate System with ages ranging 5 to 20 months old. Four of the six dogs were male and two were female. Three dogs non-descript, Labrador, Lhasa Apso and Golden Retriever each. The body weight ranged from 10 to 20 kg. Orthopaedic examination, radiography and clinical symptoms were used to diagnose long bone fractures. These fractures were stabilized with 3.5 mm Polyaxial locking plates (PAX). Radial fractures appraoched cranio-medially, a cranio-lateral approach for femur and a cranio-medial approach for tibia, allowing for bone plating with Polyaxial Locking (PAX) system. Four dogs had good implant stability without any complications. Whereas plate bending was noticed on 30th Post-operative day in two dogs. However, intermittent weight bearing was noticed by 45th post- operative day. The dogs with grade V lameness were progressed to Grade I by the end of the 30th post-operative day in four dogs, while two more had accomplished grade I at the end of the 60th post-operative day. PAX system offers angulation of locking screws, prevent growth plates from being damaged in young dogs and screw penetration in fracture lines, resulting in a rigid stabilization. Limited contact with the bone resulted in preserving the periosteal vascular, which promoted early fracture healing, limb ambulation and an earlier return to normal range of motion.

Keywords: Polyaxial, locking plate, locking screws, dogs, PAX, angulation of screws

Introduction
Long bone fractures are the most frequent orthopaedic condition seen in canine species. The causes of long bone fractures were automobile accidents and falls from height [1].

The Arbeitsgemeinschaft für Osteosynthesefragen (AO) has identified four key principles of fracture repair: Anatomical reduction, stable fixation, preservation of the blood supply and early active pain-free mobilisation [2, 3].

The bone plating and screw fixation was a very popular as well as successful fracture repair technique. Plate osteosynthesis has proven to be superior because of excellent stability provided by the plate to axial, rotational and bending forces and producing more than 98% union rates. But the use of traditional plates is also associated with complications such as pressure osteopenia and adverse effect on fracture healing. Additionally, the traditional plates require a precise anatomical contouring over the bone surface, which can interfere with the periosteal blood supply, thereby delaying the fracture healing.

In order to heal canine long bone fractures, bone plates such as Dynamic Compression Plate (DCP), Locking Compression Plate (LCP) and Limited Contact Dynamic Compression Plate (LCDCP) were frequently utilised. Advanced Locking Plate System (ALPS) and Polyaxial Locking Plate System (PAX) plates are two new plate designs that have been introduced into small animal practice with various advantages over older plates. The fixed angle limits flexibility for screw placement when there is a need to avoid joints, fracture lines and other implants.

PAX screws can be inserted multidirectionally up to 5° within the plate without a significant loss of push-out strength. At an insertion angle of 10° the push-out strength does decrease significantly; however, it is still higher than the pullout strength of 3.5 mm cortical screws in bone., The PAX system allows for Multidirectional screw insertion with an overall complication rate and time to functional union similar to other fracture repair implant systems [4].

Materials and Methods

The present study was conducted on 6 dogs with long bone fractures, brought for treatment, displayed signs such as quick onset of discomfort and lameness right after a trauma. At the fracture site, there were signs including swelling, hanging of the limb, immobility and abnormal angulation of the limb (Fig. 1).

Two orthogonal views of both fractured and normal contra-lateral limb plain Medio-lateral and cranio-caudal radiographs of the affected bone including the proximal and distal joints were found to be satisfactory to confirm the tentative diagnosis. The length of the bone as estimated from the medio-lateral and cranio-caudal radiographs obtained prior to surgery determines the length of the plates to be employed. By measuring the transcortical diameter of the femur, tibia, radius and ulna at various distances from the fracture site of the respective bones directly from the cranio-caudal radiographs taken prior to surgery, the length of the screws required for application of the poly axial locking plate (PAX) in each patient was determined. (Fig. 2).

Pre-operative patient preparation

On the injured limb, hair was clipped from a large region surrounding the fracture site, being careful to remove hair from both the upper and lower joints for maintaining asepsis. Surgical spirit was then applied after shaving and cleaning the surgical site with povidone-iodine surgical scrub.

Anaesthesia

Xylazine at the dose rate of 1mg per kg body weight along with ketamine at the dose rate of 10mg/kg body weight was administered intramuscularly. Ten minutes later propofol at the dose rate of 4mg/kg body weight was given through intravenous route slowly, following induction all dogs were intubated with endotracheal tube of suitable size. Anaesthesia was maintained with isoflurane @ 2.5 % in 100% oxygen throughout the surgical procedure.

Positioning of the Animal

The dogs with a fractured radius-ulna and tibia were positioned in lateral recumbency, with the fractured limb down and the contra-lateral limb restrained and out of the way. Dogs with femur fractures were placed in lateral recumbency with the fractured limb up.

Implants

The Polyaxial Locking plates and screws, such as the 3.5 mm PAX plate and 3.5 mm locking screws are used to stabilize fractures. Dogs weighing between 8 and 25 kg are fitted with the 3.5 mm PAX plate. (Fig. 3)

Surgical Approach to Long Bones

A cranio-medial incision from the medial epicondyle of the humerus to the styloid process of the radius was used to access the Radius and Ulna. Between the proximal extensor carpi radialis and pronator muscles, the deep antebrachial fascia was incised. with the extensor muscle running parallel to the distal part of the incision. The median nerve, brachial artery and vein were preserved. Extensor carpi radialis muscle was reflected cranially, pronator teres and flexor carpi radialis muscles were reflected caudally, exposing the body of the radius and distal radius (Piermattei and Johnson. 2004). (Fig. 4)

From the level of the greater trochanter to the level of the patella, a skin incision was made along the cranio-lateral boundary of the femur to approach the femur. Incisions were made in the superficial fascia and subcutaneous fat. Along the cranial edge of the biceps femoris muscle, the superficial fascia lata leaf was incised. The femur shaft was identified after caudal biceps femoris muscle retraction. By releasing the slack fascia between the muscle and the bone, the vastus lateralis and intermedius muscles on the cranial surface of the shaft were pulled back (Piermattei and Johnson. 2004). (Fig. 5)

A medial incision of skin was made in a straight line to reach the tibia (fig. 3. 10C). By incising the Crura fascia over the medial shaft of the bone, the bone was made visible. The muscles were made visible by raising the fascia. By cutting the fascia along the boundaries to release the cranial tibial and medial flexor muscles from the bone, they were retracted [5]. (Fig. 6)

Fracture Reduction and Plating

The fractures were fixed using the Open Reduction and Internal Fixation (ORIF) technique. The fracture was minimised and the bone fragments were aligned by applying traction and counter traction to the broken pieces. PAX plate was placed over the fractured fragments to span the entire length of the bone after contouring and the contour was then examined. The alignment of the PAX plate over the bone was checked for any deviations and the PAX plate was secured with bone and plate holding forceps. At either the proximal or distal end of the bone, the specific PAX drill guide was put over the screw hole. The bone was then drilled with the appropriate drill bit—a 2.7 mm drill bit for a 3.5 mm PAX plate—in both the cortex and the depth was measured using a depth gauge. The holes were drilled either polyaxially or perpendicularly to the PAX plate depending on the angle of PAX screw insertion with the help of PAX drill guide. The PAX plate's proximal and distal holes were initially secured with screws. The PAX plate was then fastened to the bone by inserting a screw of the appropriate length into the drilled hole and tightening it with a hexagonal orthopaedic screwdriver until the tapered end of the screw emerged from the distant cortex. The same procedure was repeated for fixing the remaining screws (Fig. 7).

Results

Selection of cases

During the course of the study, a total of 97 dog fracture instances were documented. Long bone fractures occurred in 68 cases (70.10%) out of the 97 total cases. Out of these 68 cases, fractures involving the femur occurred in 25 cases (36.76%), those involving the radius and ulna in 20 cases (29.41%), the tibia in 16 cases (23.52%) and the humerus in 7 cases (10.29%). Six dogs were chosen from among above instances as being appropriate for fracture fixation with Polyaxial locking (PAX) system plates.

Anamnesis

The age of the six dogs ranged from of 5-20 months with a mean of 9.33±2.36 months. Four of the six dogs were male and two were female. Three dogs non-descript, Labrador, Lhasa Apso and Golden Retriever each. The body weight of the dogs ranged from 10 to 20 kg with a mean of 13.62±2.02 kg.

In these six dogs the main cause for occurrence of fractures were found to be fall from height in three (50%) dogs, automobile accident in two (33.3%) dogs and animal fight in one (16.66%) dog. The dogs were presented for treatment between 1 to 15 days after fracture occurrence with a mean of 4.67±2.11 days. Concurrent illnesses were not reported in any of the dogs. Details of the cases are presented in Table 1.

Pre-operative observations

Pre-operative radiographs of the six cases also revealed the type of fracture, with three dogs having oblique fractures, one dog is having communited fracture, one dog is having spiral fracture and one is having transverse fracture. (Table.2)

Materials used

When utilised to stabilise long bone fractures, Polyaxial Locking Plates (PAX) in dogs weighing 10–20 kg, 3.5 mm PAX plates were utilized. Three dogs received PAX plates with 8 holes and three dogs received PAX plates with 10 holes. 3.5 mm self-tapping Biocritical screws that ranged in length from 14 mm to 32 mm.

Surgical procedure

A cranio-medial skin incision directly over the radius provided satisfactory exposure of fractured radial diaphysis to perform bone plating Polyaxial locking Plate system (PAX).

The craniolateral border of the arm approach provided satisfactory exposure of fractured diaphyseal region of femurs bone to perform bone plating with Polyaxial locking Plate system (PAX).

The cranio-medial border of tibia approach provided satisfactory exposure to tibia to perform bone plating using Polyaxial locking Plate system (PAX). Care was taken to protect the dorsal branch of the saphenous vessels and nerves while crossing the field at the midshaft.

Fracture Reduction and Plating

In this study, all long bone fractures were reduced and stabilized with open reduction and internal fixation technique. After the fracture was reduced, the PAX plate was contoured to match the surface of the bone and affixed to it with self-tapping screws. This made it possible to drill, insert screws in and fix things. For plate fixation, the 2.7 mm drill bit for 3.5 mm PAX plate was found to be acceptable. Screw application without tapping and positioning without involving growth plates always resulted in a successful attachment of the plate.

Post-operative Lameness Grading

All of the dogs began to partially bear weight on the second postoperative day. After surgery, four dogs advanced to grade I lameness by day 30thpost–operative and two dogs by day 60thpost–operative day. In all dogs, their functional limb outcomes evaluated and they were all graded as excellent, good, fair, or poor. (Table. 3). Five dogs scored excellent on the functional outcome test, while one dog received a good score. (Fig. 8)

Stability of Implant

In the present study with 3.5 mm Polyaxial Locking plates (PAX) Good implant stability throughout the observation period without any complications was achieved in four dogs. In one dog, plate bending was observed at fracture site in by post-operative 15th day due to jumping from height and plate bend in another dog on 30th day due to animal fight.

Post-operative radiographic observations

Post-operative radiographs revealed the progression of bone healing. The radiographs revealed good callus formation, bridging the fracture site in five the dogs. Subsequent radiographs taken on the 30th post-operative day indicated a significantly smaller bridging callus. In four dogs, the callus was smoother and more opaque and in one dog with a fractured femur, plate bending was observed by the 30th post-operative day due to an animal fight. The fracture line vanished on follow-up radiographs taken on the 60th post-operative day and cortico-medullary continuity had returned. Radiographs taken on the 90th post-operative day showed that the bone had fully healed and had clear cortico-medullary continuity as a result of the reshaping of the excess callus. (Fig. 9)

Complications

In one dog, plate bending was observed at fracture site by post-operative 15th day due to jumping from height and plate bend in another dog on 30th day due to animal fight. (Fig. 10)

Discussion

During the course of the investigation, Out of these 97 occurrences, long bone fractures were seen in 68 cases (70.10%). From these 68 cases, 25 (36.76%) associated femur fractures, 20 (29.41%) involved radius and ulna fractures, 16 (23.52%) involved tibia fractures and 7 (10.29%) involved humerus fractures. These results were in accordance with [6-9]. In contrary to this [10, 11] who reported femur fractures 45%, 25% radius ulna fractures 16%, 17% tibia fractures 26%, 19.5% respectively.

Among six cases were considered to be suitable for fracture fixation with polyaxial locking plates (PAX) the age of the dogs ranged from of 5-20 months with a mean of 9.3±2.36 months, these were in accordance with [8, 9, 11, 12]. Out of these six dogs, four were males and two were female, this is in accordance with [9, 13, 14]. Among them one dog was Lhasa Apso breed, one dog was Labrador, one dog was Golden Retriever and rest of the dogs were Mongrels. This finding was similar with [12]. These results differed with observation of [11, 15]. The body weight of the dogs ranged from 4.5 to 12 kg with a mean body weight of 7.16±0.91 kg.

Out of the six dogs, the main cause of fracture was found to be jump from height in three (50%) dogs, followed by automobile accident in two (33.3%) dogs, Animal fight in one dog (16.6%) is reported. These findings were in accordance with [8, 16, 17]. It was found in the present study that the dogs with fractures were presented for treatment between 1 to 15 days with a mean of 4.67±2.11 days after sustaining fracture.

In the present study, the clinical signs of fracture noticed were pain on manipulation, abnormal angulation and lameness. Similar observations were recorded [14, 18, 19, 20, 21].

Preoperative radiographs revealed 5 mid-diaphyseal (83.33%) and 1 distal diaphyseal (16.66%) fractures. Out of six dogs in the present study 3 dogs had complete oblique fractures (50%), 1 dog had complete transverse fractures (16.66%), one dog had a complete spiral fracture (16.66%) and one dog had a complete communited fracture (16.66%). These finding were in congruence with [16, 22, 23]. stated occurrence of long bone fracture is more in the middle and proximal third of the diaphysis,

Xylazine and ketamine were administered in combination intramuscularly. Propofol was administered through intravenous route slowly for inducing general anaesthesia 10 minutes later. Anaesthesia was maintained with isoflurane @ 2.5 % in 100% oxygen during the surgical procedure which was considered satisfactory [24, 25] also adopted similar anaesthetic protocol in their study.

The length of the fractured bone decided based on the pre-operative radiographic measurements, three 3.5mm, 10-hole PAX plates and three 3.5mm, 8-hole PAX plates were utilised for dogs weighing 10 kg to 20 kg. These matched the findings of (De Camp 2015, Klug *et al.* 2018) who suggested choosing the plate depending on the patient's body weight, the size of the bone and the type of fracture.

In this study, all the long bone fractures were reduced and stabilised with open reduction and internal fixation technique and based on the body weight of the dog, 3.5mm PAX plate was used. In cases 3 and 4, which involved radial and ulnar fractures, the PAX plate's angled screws provided the surgeon with more flexibility, especially when the distal fragment is relatively small. They also prevented screw penetration into the antebrachio carpal joint by angling the screws away from the articular surface as observed by [28-32]. In cases 2 and 6, which had femur fractures, PAX plate fixation provided an additional benefit by deflecting the screw away from the fracture site and creating a secure framework for rapid fracture healing. This was in accordance with the studies of[33] who observed that screw angulation did not affect the overall strength of the construct.

Tibia and fibula fractures occurred in cases 1 and 5, respectively. By avoiding the oblique fracture line and the joints above and below, the placement of a PAX plate assisted in the fixing of a fracture in the tibial metaphysis by screw pathway adjustment, resulting in satisfactory fracture reduction and stability which was in accordance with the reports of [29, 31, 34].

In all the cases, PAX screw fixation needed additional insertion force to drive and lock the PAX screws in the plate for the screws to cut threads into the plate and securely lock into the plate which agreed with the findings of [35]. There was no screw loosening, screw breakage or loss of screw plate interface which agreed with findings of [36].

Over the course of the study, the lameness grade post-operatively gradually improved to permit for normal weight bearing. The lameness grade was conducted in accordance with the [37]. All dogs pre-operative lameness scores, grade V lameness prior to surgically stabilising the fracture. By the end of the 30th post-operative day, four dogs advanced to grade I lameness and two more had reached grade I lameness by the end of the 60th post-operative day.

The radiographic evaluation revealed good apposition of the fracture ends. Radiographic evaluation of fracture healing was routinely performed at the time of expected clinical union [38, 39]. In five cases, follow-up radiographs taken on the 15th post-operative day showed that the fracture fragments were properly positioned and aligned, although in one dog, plate bending was observed in the femur due to a subsequent fall from height by the 15th post-operative day. Follow-up radiographs obtained on 30th post-operative day revealed bridging callus considerably reduced in size. The callus was smoother and more opaque and the radiolucent fracture line was faintly visible in four dogs however in one dog with femur fracture Plate bending was noticed by 30th post-operative day due to Animal fight. The fracture line vanished on follow-up radiographs taken on the 60th post-operative day and cortico-medullary continuity had regained. On the 90th post-operative day, radiographs taken showed full bone healing with distinct cortico-medullary continuity brought on by the remodelling of excess callus.These findings are in agreement with [13, 38, 40].

Due to a subsequent fall from a height in one dog and an animal conflict in another dog, plate bending was shown at the fracture site by the post-operative 15th and 30th days, respectively [41].

Fig 1: Pre –operative Non weight bearing of fractured limbs in all six dogs.

Fig 2: Pre-operative Radiograph (medio-lateral and cranio-caudal view) in all dogs

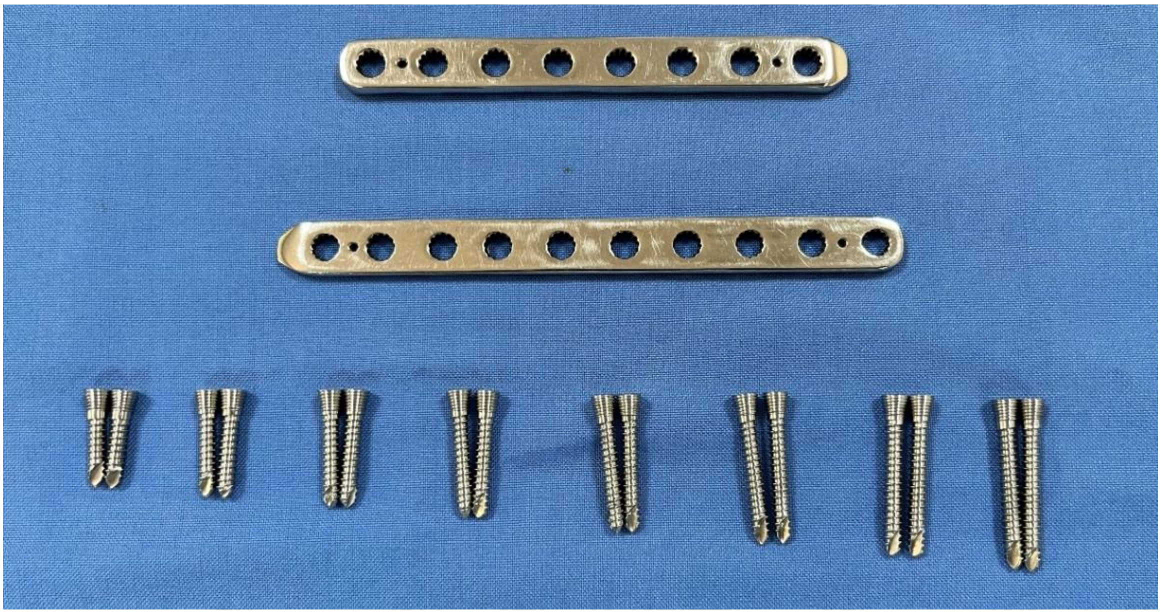

Fig 3: 3.5 mm PAX plates (8 Holes and 10 Holes) and different lengths of 3.5 mm screws

Fig 4: Cranio- medial skin incision made directly over Radius shaft

Fig 5: Cranio-lateral incision made directly over femur shaft

Fig 6: Cranio-medial incision made directly over Tibial shaft

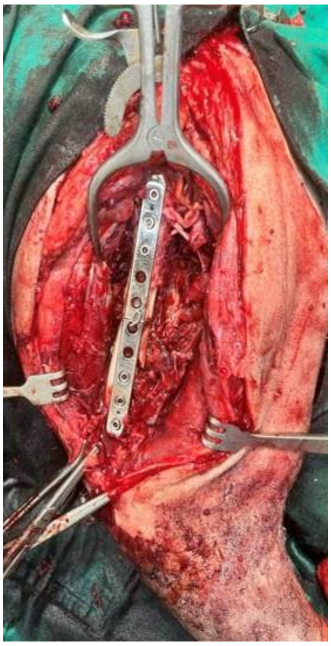

Fig 7: Bone plating (PAX) completed in Radius, Femur and Tibia.

Fig 8: Progressive weight bearing on different post-operative days

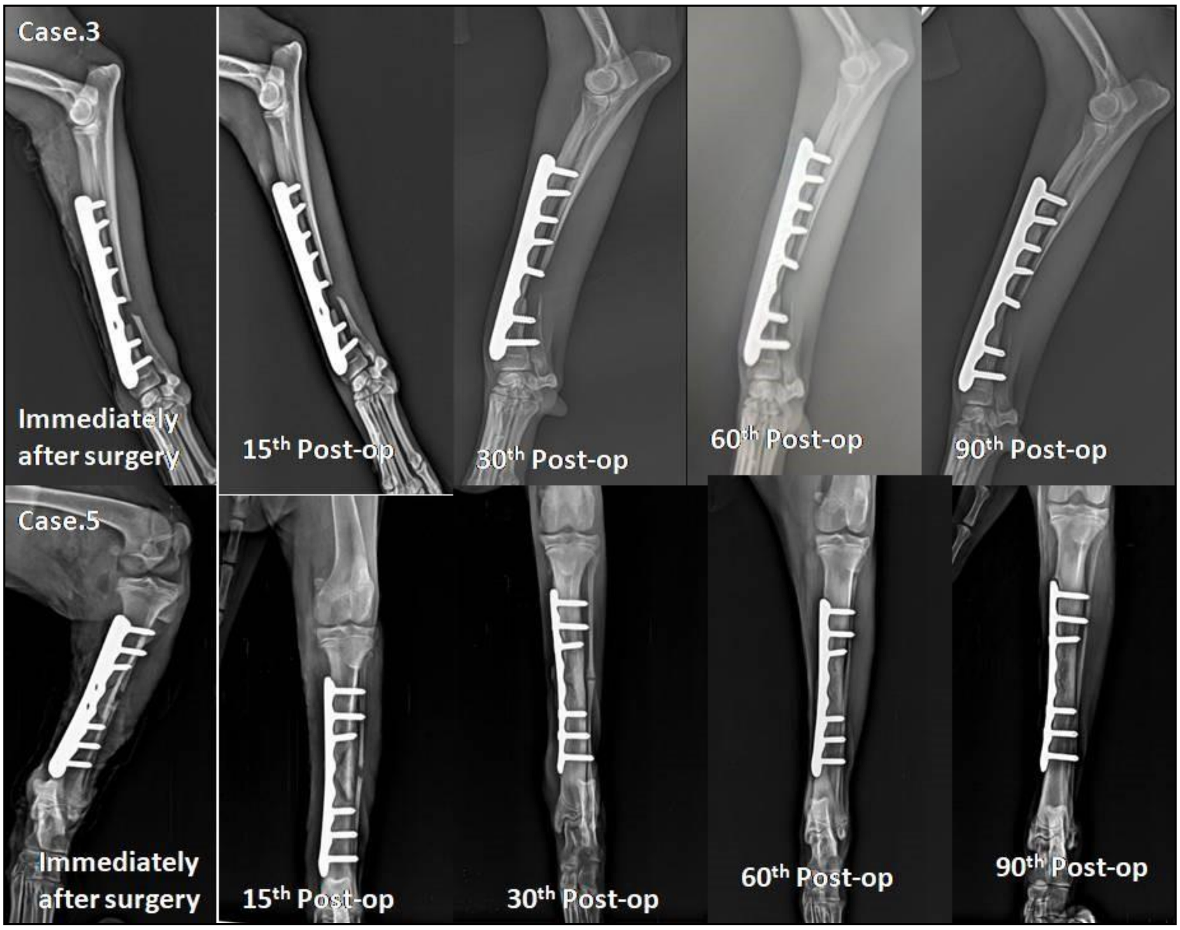

Fig 9: Progressive Radiographic changes in dog with radial and tibia fracture

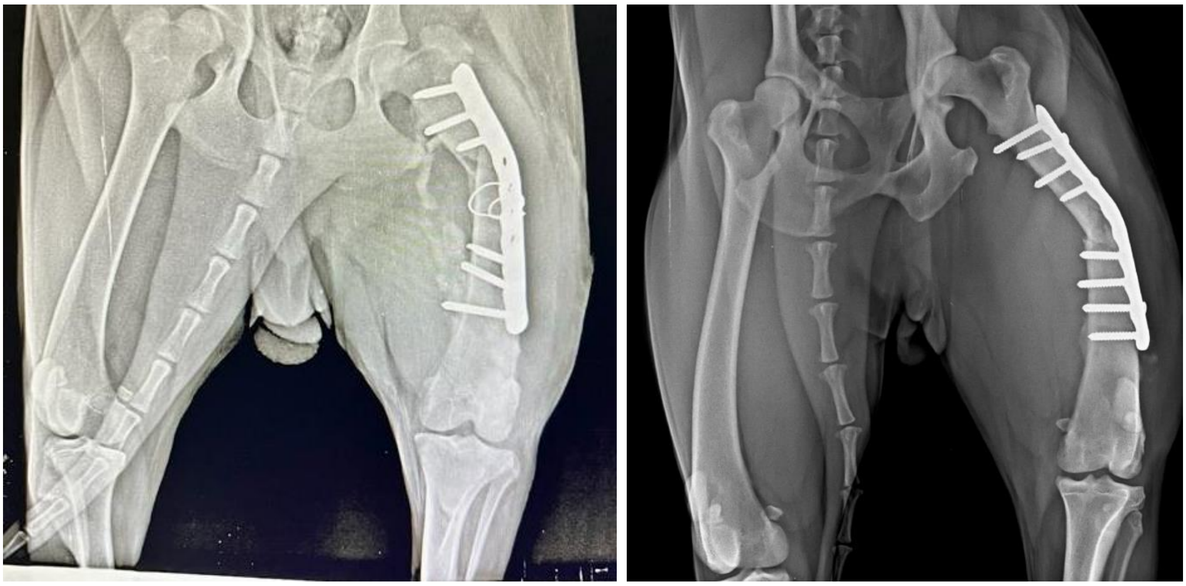

Fig 10: Bending of plate on 15th post operative day and 30th post operative day in case of femur fracture stabilization with PAX

Table 1: Clinical history of the dogs selected for the study

Case no.	Breed	Age (months)	Sex	Body weight (kg)	Cause	Days since fracture
1	Mongrel	6	Male	12	Automobile accident	3
2	Mongrel	20	Male	20	Animal Fight	2
3	Lhasa Apso	12	Male	10.7	Fall from height	1
4	Mongrel	6	Female	10	Automobile accident	15
5	Golden Retriever	5	Female	11	Fall from height	4
6	Labrador	7	Male	20	Fall from height	3
Mean		9.33±2.36		13.62±2.02		4.67±2.11

Table 2: Pre-operative radiographic observations

Sl No	Affected side	Location of fracture	Type of fracture
1.	Right hindlimb	Mid-diaphyseal of Tibia	Complete oblique overriding
2.	Left hindlimb	Mid-diaphyseal of Femur	Complete oblique overriding
3.	Right forelimb	Distal diaphyseal of Radius Ulna	Complete oblique overriding
4.	Right forelimb	Mid-diaphyseal of Radius Ulna	Complete communted overriding
5.	Left hindlimb	Mid-diaphyseal of Tibia	Complete transverse overriding
6.	Left hindlimb	Mid-diaphyseal of Femur	Complete spiral communted overriding

Table 3: Post-operative details of lameness grading

Case No	PAX	Pre- operative Lameness Grading	Post-operative lameness grades				
			Day 1	Day 15	Day 30	Day 60	Day 90
1	3.5 mm	V	IV	II	I	I	I
2	3.5 mm	V	IV	III	II	I	I
3	3.5 mm	V	III	II	I	I	I
4	3.5 mm	V	III	II	I	I	I
5	3.5 mm	V	III	II	I	I	I
6	3.5 mm	V	IV	III	II	I	I
Mean±SE		**5.00±0.00**	**3.50±o.22**	**2.50±0.21**	**1.33±0.21**	**1.00±0.00**	**1.00±0.00**

Grade V- Does not bear weight on limb at rest or while walking.
Grade I- Normal weight bearing on all limbs at rest and while walking.
Grade II- Normal weight bearing at rest, favours 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.

Conclusion

Based on the results of the current study, Polyaxial Locking Plates (PAX) were effective in treating long bone fractures and provided four out of six dogs with good recompense and a noticeably improved level of limb function. Treatment of long bone fractures with Polyaxial Locking Plates (PAX) fixation was found to be successful because it offered resistance to axial, bending and torsional forces operating on the bone.

Conflict of Interest Nil

References

1. Marvania NT, Tank PH, Vadalia JV, Singh VK, Kamaliya RU. Comparative assessment of minimally invasive plate osteosynthesis and open plating for repair

of long bone fracture in dogs. Indian Journal of Veterinary Surgery. 2020;41(1):1-5.
2. Gautier E, Perren SM and Ganz R. Principles of internal fixation. Current Orthopaedics. 1992;6(4):220-32.
3. Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: Choosing a new balance between stability and biology. Journal of Bone Joint Surgery. 2002;84:1093-1110.
4. Bamhart MD. The Polyaxial (PAX) advanced locking system. locking plates in veterinary Orthopaedics. John Wiley & amp; Sons; c2018. p. 87-90.
5. Piermattei DL, Johnson KA. An atlas of surgical approaches to the bones and joints of the dog and cat, Philadelphia, Saunders; c2004. p. 416
6. Libardoni RN, Serafini GMC, Oliveira C, Schimites PI, Chaves RO, Feranti JPS, *et al*. Appendicular fractures of traumatic etiology in dogs:955 cases. Ciência Rural, Santa Maria. 2016;46(3):542-546.
7. Jain R, Shukla BP, Nema S, Shukla S, Chabra D, Karmore SK. Incidence of fracture in dog: A retrospective study. Veterinary Practitioner. 2018;19(1):63-65.
8. Kallianpur N, Singh K, Gopinathan A, Sarangom SB, John C, Sowbharenya C *et al*. Investigation on relation between factors affecting occurrence and outcome of repair of long bone fractures in 216 dogs. International Journal of Livestock Research 2018;8(2):225-234.
9. Kumar H, Tyagi SP, Amith K, Adarsh K, Singh S. Incidence of fractures in animals Indian Journal of Veterinary Surgery. 2019;41(1):1-5.
10. Harasen G. Common long bone fractures in small animal practice. Canadian Veterinary Journal. 2003;44:333-334.
11. Maruf M, Hwang Y, Park M, Kim S, Cheongjin Oh, Choi S *et al*. Retrospective study on fractures in dogs. Journal of Biomedical Research. 2013;14(3):140-144.
12. Simon SM, Ganesh R, Ayyappan S, Rao GD, Suresh Kumar R, Kundeve VR, *et al*. Incidence of pelvic limb fractures in dogs: A survey of 478 cases. Veterinary World. 2010;3(3):120-121.
13. Reddy JMK, Kumar DD, Sekhar CEL, Srikanth Kulkarni, Vijay Kumar M and Dr. Dhoolappa M. Clinical study on the use of Titanium Dynamic Compression Plate (Ti-DCP) for repair of femur fractures in dogs. The Pharma Innovation Journal. 2020;9(12):08-18.
14. Bhoomaiah M, Reddy JMK, Sekhar CEL, Latha C, Rajendranath N. A clinical study on the use of string of pearls plate system in stabilization of long bone fractures in dogs. The Pharma Innovation Journal. 2022;9(12):08-18.
15. Gahlod BM, Dhakate MS, Patil SN, Gawande PS, Kamble MV. Retrospective study of fractures in canines-A report of 109 cases. Indian Journal of Veterinary Surgery. 2004;25(2):122-142. Abstracts, XXVIII Annual Congress of Indian Society for Veterinary Surgery.
16. Aithal HP, Singh GR and Bisht GS. Fractures in dogs:A survey of 402 cases. Indian Journal of Veterinary Surgery. 1999;20:15.
17. Kushwaha RB, Gupta AK, Bhadwal MS, Kumar S, Tripathi AK. Incidence of fractures and their management in animals: A clinical study of 77 cases. Indian Journal of Veterinary Surgery. 2011;32(1):54-56.
18. Chaurasia A, Jawre S, Singh R, Shahi A, Pathak R, Das B *et al*. Evaluation of Haemato-Biochemical Parameters using Different Biomaterials in Fracture Healing of Dogs. International Journal of Current Microbiology and Applied Sciences. 2019;8(05):2265-2271.
19. Kumar SP, Prasad AA, Shafiuzama M, HP and Barathidasan M. Polyaxial locking plate (pax) in management of oblique diaphyseal fracture of tibia in 8 months old Labrador. Indian Veterinary Journal. 2021;98(1):43 to 45
20. Tyagi SK, Aithal HP, Kinjavdekar P, Amarpal AM, Saxena AK. Acrylic and Epoxy-pin External Skeletal Fixation Systems for Fracture Management in Dogs. Indian Journal of Animal Research. 2021;1:8.
21. Reddy JMK, Kumar DD. Clinical Efficacy on the Use of Titanium Intramedullary Interlocking Nailng (Ti-IILN) for Repair of Communited Diaphyseal Femur Fractures in Dogs. Journal of Animal Research. 2021;11(05):807-817.
22. Ali BLM. Incidence, Occurrence, Classification and Outcome of Small Animal Fractures: A Retrospective Study (2005-2010). World Academy of Science, Engineering and Technology. 2013;7(3):191-196.
23. Raouf MAE, Ezzeldein SA, Eisa EFM. Bone fractures in dogs: A retrospective study of 129 dogs. Iraqi Journal of Veterinary Sciences. 2019;33(2):401-405
24. Chanakya T, Reddy JMK, Sekhar CEL, Rao MT, Kumar PD. A clinical study on use of point contact fixator plate system (PC-FIX) in the treatment of radius ulna fractures in dogs. The Pharma Innovation Journal. 2021;10(8):164-170.
25. Abhishek B, Reddy JMK, Chandrasekhar EL, Rao RKJ, Rajendranath N. Clinical study on repair of tibial fractures using intramedullary interlocking nailing in dogs. The Pharma Innovation Journal. 2022;11(11):1755-1761.
26. Camp DCE. Brinker, Piermattei and Flo's handbook of small animal orthopedics and fracture repair (4th Ed.). Elsevier Health Sciences. Missouri, 2015, 8.
27. Klug A, Gramlich Y, Buckup J, Wincheringer D, Hofmann R, Schmidt-Horlohé K. Excellent results and low complication rate for analoniepolyaxial locking plates in comminuted proximal ulna fractures. Journal of Shoulder Elbow Surgery. 2018;27(12):2198-2206.
28. Wilkens KJ, Curtiss S, Lee MA. Polyaxial locking plate fixation in distal femur fractures: A biomechanical comparison. Journal of Orthopaedics and Traumatology. 2008. 22:624-628.
29. Gao H, Zhang Q, Luo CF, Zhou Z, Zeng B. Fractures of the distal tibia treated with polyaxial locking plating. Clinical Orthopaedics. 2009;467:831-837.
30. Sirbu PD, Petreus T, Asaftei R, Cotrutz CE, Carata E, Botez P, *et al*. Minimally invasive plate osteosynthesis using systems with angular stability in complex fractures of the distal femur. Romanian Neurosurgery. 2011;18(1):101-102.
31. Zettil R, Müller T, Topp T, Lewan U, Krüger A, Kühne C, *et al*. Monoaxial versus polyaxial locking systems:a biomechanical analysis of different locking systems for the fixation of proximal humeral fractures. International Orthopaedics (SICOT). 2011;35:1245-1250.
32. Bufkin, BW, Barnhart MD, Kazanovicz AJ, Naber SJ, Kennedy SC. The effect of screw angulation and insertion torque on the push-out strength of polyaxial locking screws and the single cycle to failure in bending of polyaxial locking plates. Veterinary and Comparative

Orthopedics and Traumatology. 2013;26:186-191.
33. Ruchholtz S, El-Zayat B, Kreslo D, Bu' oking B, Lewan U, Kruger A, *et al*. Less invasive polyaxial locking plate fixation in periprosthetic and peri-implant fractures of the femur. Injury - International Journal of Care of the injured. 2013;44:239-248.
34. Nikolaou VS, Tan HB, Haidukewych G, Kanakaris N, Giannoulis PV. Proximal tibial fractures: early experience using polyaxial locking-plate technology. International Orthopaedics. 2010;35:1215-1221.
35. Tomlinson AW, Comerford EJ, Birch RS, Innes JF, Walton MB. Mechanical performance in axial compression of a titanium polyaxial locking plate system in a fracture gap model. Veterinary and Comparative Orthopaedics and Traumatology. 2015;28:88-94.
36. Kaczmarek J, Bartkowiak T, Schuenemann R, Paczos P, Gapinski B, Bogisch S, *et al*. Mechanical performance of a polyaxial locking plate and the influence of screw angulation in a fracture gap model. Veterinary and Comparative Orthopaedics and Traumatology 2019;33(1):36-44.
37. Vasseur PB, Johnson AL, Buderberg SC, Linwin JB, Toombs JP, Whitebain JG, *et al*. Randomized, controlled trials of the efficacy of carprofen, a non-steroidal anti-inflammatory drug in the treatment of osteoarthritis in dog. Journal of American Veterinary Medical Association. 1995;206:807-811.
38. Piermattei DL, Flo GL, Brinker WO. Fracture classification, diagnosis, and treatment. Handbook of Small Animal Orthopedics and Fracture Repair, 5th Ed by Elsevier Missouri; c2016. p. 24-149.
39. Langley-Hobbs S. Biology and radiological assessment of fracture healing. In Practice. 2003;25:26-35.
40. Aikawa T, Miyazaki Y, Shimatsu T, Lizuka K, Nishimura M. Clinical outcomes and complications after open reduction and internal fixation utilizing conventional plates in 65 distal radial and ulnar fractures of miniature and toy- breed dogs. *Veterinary and* Comparative Orthopaedics and Traumatology. 2018;31(3):214-217.
41. Vallefuoco R, Pommellet LH, Savin A, Decambron A, Manassero M, Viateau V, *et al*. Complications of appendicular fracture repair in cats and small dogs using locking compression plates. Veterinary and Comparative Orthopaedics and Traumatology. 2016;29:46-52.