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Evaluation of minimally invasive plate Osteosynthesis for long bone fractures in dogs

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Abstract
The aim of this study was to evaluate minimally invasive plate osteosynthesis for long bone fracture especially tibia-fibula and radius-ulna in six clinically affected dogs. Pre and post-operative assessment was done on the basis of critical clinical examination and radiographic evaluation. Radiographs were taken post-operatively at 15th and 45th day and for hematobiochemical examination blood was collected in standard manner at 0, 7th and 15th post-operative days for evaluation of healing process. Hematological parameters were found within the normal range before and after surgery probably due to supportive therapy and absence of post-operative infection. Difference in biochemical parameters on the day of surgery and post-operative period was in accordance with healing process. Radiographic evaluation, lamemess grading and functional outcome revealed that the procedure provided adequate reduction and alignment of fracture ends depended on factors like type and duration of fractures.

Keywords: Fracture, healing, biochemical parameters, radiographic evaluation

Introduction
Long bone fracture are common in dogs. Mostly tibial and radial fractures are stabilized with external coaptation but sometimes it results in malunion or other fracture diasease. Open reduction and internal fixation technique for long bone fracture repair affects blood supply near the site of fracture and decreases bone perfusion. Biological osteosynthesis technique enhance the healing process by balancing biology and mechanics at the fracture site by orthopaedic technique which is obtained by applying minimally invasive techniques, namely percutaneous plate insertion, interlocking nailing, external fixation or a combination of these technique. One of the most imperative evolutions of biological internal fixation is Minimally Invasive Plate Osteosynthesis (MIPO). MIPO technique is more advantageous in highly cominutive and multiple fractures. Although this technique is easier to perform on radius-ulna and tibia-fibula fracture as compare to humerus and femur fracture because lesser muscle coverage around these bones which improves the close reduction of fractured fragments. Aim of this study was to apply MIPO in long bone fractures and assess the healing by radiographic and clinical examination.

Materials and Methods
Pre-operative preparation and anesthesia: The clinical study was carried out in six dogs having tibial and radial fractures diagnosed by clinical evaluation and radiographic examination. Pre-operative assessment of patients were done on the basis of history and clinical examination. Following the initial clinical assessment, the dogs were subjected to pre-operative radiographic examination in two orthogonal view (medio-lateral and cranio-caudal). All owners granted written informed consent prior to surgery. Atropine sulphate[1] (0.04 mg/kg body) weight was administered subcutaneously as pre-anaesthetic followed by, intravenous injections of Diazepam (0.5 mg/kg body weight) and Ketamine (10 mg/kg body weight) were administered simultaneously for induction of general anesthesia. After the induction, the dogs were intubated with endotracheal tubes of suitable size. After intubation, anaesthesia was maintained by 2.0 to 2.5 % isoflurane[4] with oxygen. The dog was positioned in lateral recumbency with the affected limb below and contralateral limb above on the operation table.
Implant: A general instrumentation set and orthopaedic set 2.7 mm and 3.5 mm dynamic compression plate (4-8 holes) and cortical screws (2.7 mm and 3.5 mm) were used in the study.

Surgical procedure: For MIPO, tibia and radius was approached through medial and cranio-medial side of the bone respectively. Closed reduction was carried out by "manual traction" method. A gauze or rope loop was placed around the axillary or groin region and anchored to the edge of the table near the animal's back. Another gauze or rope loop was placed around the carpal or tarsal area, and traction was applied against the first rope. Relaxation of muscle was accomplished by a slow, progressive increase of traction tension over 10 to 30 minutes. After proximal and distal skin incision at respective site, the contoured plate was inserted through proximal incisions and slide through the soft tissue tunnel adjacent to the surface of the bone and over the fracture site until the end of the plate was visible at the distal incision. The plate was positioned on the bone and one or two appropriate screws were placed to secure the proximal segment to the plate. The alignment of the limb was reassessed to determine the normal angulations and fracture stability. Screws were then placed through the remaining accessible holes via both the proximal and distal insertion incisions. A minimum of two screws were placed in each proximal and distal fracture fragments. Selection and placement of screws were similar to the standard DCP procedure. The C-arm image intensifier was focused in such a way to capture the entire length of the plate and was used to confirm if the plate was properly contoured and positioned on to the bone. Serial images were taken during the procedure. The surgeons were protected with lead aprons throughout the fluoroscopic exposure.

Post-operative care: Postoperatively, Cephalexin (25 mg/kg) and Tramadol (4 mg/kg) were given orally for 5 to 7 days. Postoperative complications were observed and recorded in both the groups. Clinical evaluation: The radiographic evaluation was assessed on immediate post-operative day based on 'four A's (apposition, alignment, angulation and apparatus) and follow-up radiographs based on 'six A's (apposition, alignment, angulation, apparatus, activity and architecture) [1].

Lameness evaluation*:* A lameness grade was assigned on the basis of severity of clinical signs on 0, 15th, and 45th postoperative day in each groups of the dog to assess response to the treatment. Weight bearing was graded as follows [2].

Functional outcome*:* Functional outcome was evaluated on the 60th postoperative day and categorized as excellent, good, fair and poor in both groups of dog [3]. The assessment was subjective and based on individual evaluation.

Blood sampling*:* From each dog, 6 mL of blood was collected for evaluation of hematological (Hemoglobin, Packed cell volume, Total erythrocyte count, Total leukocyte count and Differential leukocyte count) and biochemical parameters (Creatine kinase, Alkaline phosphatase, Calcium and Phosphorus).

Results and Discussion

Pre-operative radiography: Medio-lateral and cranio-caudal radiographs of affected bones, including proximal and distal joints confirmed the tentative diagnosis. Preoperative plan using the medio-lateral and cranio-caudal radiographs of the contralateral limb is essential to determine the size and length of the plate and screws in both groups. Two radius-ulna and four tibia-fibula fractures were present in this study. Out of six dogs, three transverse, two oblique and a comminuted fracture were included.

Surgical procedure: Tibia was approached medially and radius was approached cranio-medially through a minimal 2 to 4 cm two linear skin incisions proximal and distal to the bone. This approach was used for radius-ulna and a medial approach for tibia in all the cases in the present study [4] [5] [6]. Manual traction method was found to be appropriate in all the cases except case no. 3. Alignment and apposition of fracture was technically demanding. Complete reduction could not be accomplished in all cases with transverse and short oblique fractures. However, using indirect reduction technique by manipulation and C-arm guidance were more beneficial. The technique of plate insertion was easy to perform and creation of epiperiosteal tunnel was facilitated using a long straight artery forceps. MIPO with C-arm guidance procedure facilitated proper implant position, fracture reduction and alignment. The up/down, angulation, horizontal, swivel and the orbital movement of the C-arm facilitated accurate imaging of the bones. Intra-operative evaluation of reduction and alignment of fracture fragments and proper positioning of contoured plate to the bone was technically easier to perform under C-arm guidance.

Implant: 8 hole 2.7 mm narrow dynamic compression plate was used in case no.1 and 4, whereas, 6 hole 2.7 mm narrow dynamic compression plate was used in, case no. 3 and 6. Further, in fracture fixation of case no. 2 and 5, a 8 hole 3.5 mm narrow dynamic compression plate was applied. In the present study, longer plates were used to span the entire length of the bone. Longer plates reduced the stress on each screw so that lesser screws were required for fracture stabilization. In all the cases, 2 screws were applied proximally and 2 screws distally except in case no. 5, where only 1 screw was applied distally. The size of the cortical screws ranged from 16 mm to 20 mm for dogs with body weight ranging from 5 to 9 kgs and 18 mm to 24 mm for dogs with body weight ranging from 19 kgs to 22 kgs.

Radiographic evaluation: Case no. 1, 4 and 5 achieved a good reduction immediately post-surgery whereas, case no. 2, 3 and 6 accomplished moderate reduction which was maintained further. Radiographs were taken pre-operatively and immediately after surgery to record the status of reduction, alignment and fixation [7].

Post-operative radiographic evaluation based on six A's was performed using follow-up radiographs taken on 15th and 45th post-operative days. Post-operative radiograph showed good apposition and alignment between fracture fragments and good implant stability throughout the period of observation. However, case no 1 and 6, resulted in plate dislodgement which was seen in radiograph of 15th post-operative day. Hence the fracture was healed after removal of implant and bridging callus was seen at 45th day post-operative radiograph in both the cases but in one cases malunion of fractured fragment was formed. Post-operative implant failure occurred infrequently and was similar to those seen with other internal fixation [8]. Osteolysis was noticed at the fractured ends on 15th post-operative day radiograph of dogs. The healing in young animals takes place more rapidly than older animals [9].

Lameness grading: In lameness grading score, grade II was

observed at 15th post-operative day in case no. 2, 3, 4 and 5. In case no. 1 and 6 grade III was observed at 15th post-operative day. Normal weight bearing was observed at 60th post-operative day in case no. 1 and 6, wherever, normal weight bearing was observed at 30th post-operative day in case no. 2, 3, 4 and 5 (Table 1). Post-operatively lameness grade showed gradual improvement to normal weight bearing over the period of study. Normal weight bearing on all limbs at rest and when walking which was graded as I and this was attributed to adequate fracture reduction with plate load sharing between implant and bone and minimal disruption of the soft tissue. In the present study, the lameness grading score is in accordance with the fundamental principle of AO/ASIF which aims to promote pain free mobility through stable internal fixation and preservation of vascularity with minimal soft tissue trauma.

Table 1: Post operative lameness grading

Case no.	Pre-operative	Post-operative				
		7th	15th	30th	45th	60th
1	V	IV	III	II	II	I
2	V	III	II	I	I	I
3	V	III	II	I	I	I
4	V	III	II	I	I	I
5	V	IV	II	I	I	I
6	V	IV	III	III	II	I

Functional outcome: Functional outcome was graded as excellent in 5 cases and good in 1 case at 60th post-operative day. Good functional outcome in one case might be due to the malunion of the fractured bone (Table 2).

Table 2: Functional outcome of affected limb

Case no.	1	2	3	4	5	6
Excellent	-	+	+	+	+	+
Good	+	-	-	-	-	-
Fair	-	-	-	-	-	-
Poor	-	-	-	-	-	-

Intraoperative complications: MIPO procedure was technically demanding in unstable fractures. Reduction and alignment of fracture fragments depended on the extent of muscle relaxation, the presence or absence of soft tissue adhesions, type of the fracture and time since its occurrence. Case no. 1, 4 and 6 underwent surgical intervention less than 48 hours of fracture occurrence could be manipulated to position more easily. In the same group case no. 2, 3 and 5 surgical intervention was performed after 5 to 11 days of fracture that was difficult to manipulate.

Post-operative complication: Dislodgment of proximal screw and angulation of fractured fragments was observed in case no. 1 and 6. However, rest of the cases healed uneventfully.

Hematological parameters: In the present study, all the hematological parameters were within the normal reference range at pre-operatively and, 7th and 15th day post-operatively. Higher values of inflammatory cells indicates infection or other pathological changes but in this clinical study, selection of suitable antibiotics and analgesics at pre and post-operative period to control infection and enhance the sustainability of animals against the pathological condition rendered the increase in neutrophil count. This is suggestive of optimum perioperative clinical and therapeutic management.

Biochemical parameters: For biochemical evaluation of fracture healing and tissue damage the parameters like phosphorus, calcium, alkaline phosphatase and creatine kinase were measured at pre-operatively and, 7th and 15th post-operative days. The data was statistically analyzed by one way ANOVA and mean was compared by Duncan's multiple test range for multiple comparisons (Table 3).

Table 3: Comparison of biochemical parameters on day 0, 7 and 15

Sr. no.	Parameters	Unit	Day		Ref. value
1	Creatine kinase (CK)	U/L	0	65.37±13.26	51-368
			7	77.06±11.66	
			15	66.98±04.96	
2	Alkaline phosphatase (ALP)	U/L	0	190.95±46.05 b	5-114
			7	125.97±22.22 ab	
			15	078.87±08.41 a	
3	Calcium (Ca)	mg/dL	0	06.18±00.67 a	9.1-11.7
			7	06.69±00.22 a	
			15	08.95±00.22 b	
4	Phosphorus (P)	mg/dL	0	05.41±00.34 a	2.5-5.3
			7	05.10±00.31 a	
			15	06.17±00.40 a	

Phosphorus: On the basis of calcium phosphorus homeostasis, a high phosphorus level result in a low calcium level which facilitates binding of calcium with phosphate and deposition in the tissue. In the present study, calcium concentration was lower than normal reference range and phosphorus concentration was at higher side of the reference range. The mean value of phosphorus gradually increased from day 0 to day 7 and 15. However the difference was non-significant ($P > 0.05$).

Calcium: Upon action of alkaline phosphatase by osteoclasts, the calcium mobilize from bone fragments and plasma as long as the pH is on acidic side. Later, it becomes deposited when the reaction slowly turns alkaline, and forms the primary bone callus. Increased serum phosphate along with decreased serum calcium favors calcium deposition in tissue. In this study we found that the calcium level was lower than the normal reference range at day 0, 7 and 15. Furthermore, mean value of calcium concentration was significantly higher on day 15 as compare to day 0.

Creatine kinase: Creatine Kinase is considered as muscle specific enzyme. Increase in CK activity following muscle injury occurs rapidly (peaking in 6-12 hours) but also decline rapidly (a day or two) because CK has a short half-life of about 2 hours. Thus, persistent increase in CK activity indicate ongoing muscle damage. Mean value of CK activity varies within the normal range and there was no significant difference observed in mean values on day 0, 7 and 15.

Alkaline phosphatase: Alkaline phosphatase is the enzyme released by osteoclasts, which facilitates release of calcium phosphate from plasma so it cause super saturation of calcium in the hematoma surrounding the fracture, even if there is no appreciable variation in the general blood calcium level. Inflammation and necrosis in the tissue cause an elevation of serum alkaline phosphatase activity due to enzyme leakage. Mean alkaline phosphatase activity in serum on day 0 was higher than the normal reference range indicating substantial degree of tissue damage. The activity decreased significantly

on day 15. The gradual decrease in alkaline phosphatase activity was probably due to lesser leaching of this enzymes from damaged tissues and this specify that the tissue was healing.

Conclusion

MIPO procedure was technically demanding and required additional skill for routine clinical application. On the other hand, gradual change in biochemical parameters was in accordance to the healing process and regenerative change.

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