RESEARCH ARTICLE

# Evaluation of Modified Advanced Locking Plate System by MIPO and ORIF Techniques for Tibial Fracture Repair in Dogs

Hanchinamne Shivamurthy Pooja, Dilipkumar Desai, Manjunath Patil*

## Abstract

The study was conducted on 12 clinical cases of dogs with tibial fractures, which were randomly divided into two groups consisting of six dogs in each group. In group I (n=6), fractures were repaired by minimally invasive plate osteosynthesis (MIPO) using 3.5 mm modified advanced locking plate system (ALPS) with a plate width of 10 mm and in Group II (n=6), fractures were repaired by open reduction and internal fixation (ORIF) techniques using 3.5 mm modified advanced locking plate system with a plate width of 10 mm. Based on clinical, biochemical and radiological evaluation, the healing of the fracture was studied at intervals of 0, 15$^{th}$, 30$^{th}$, and 60$^{th}$ post-operative days. Both groups underwent clinical evaluations of weight bearing, functional limb usage and lameness grading at particular interval. On clinical observations of weight bearing (functional outcome and lameness grading), dogs treated with MIPO showed early weight bearing compared to ORIF technique. The biochemical parameters obtained on the 0, 15$^{th}$, 30$^{th}$ and 60$^{th}$ day showed a fluctuating trend. However, values were within the normal physiological limit. Post-operative radiographic evaluation showed progressive healing of fracture site with lesser callus formation in group I compared to group II. Post-operation complication of plate bending observed in one case on 5$^{th}$ day and wound dehiscence in two dogs of group II. In conclusion, both techniques with modified ALPS provided adequate stability and immobilisation of fracture fragments, allowing early ambulation with tibial fractures, whereas MIPO technique provides early functional outcome of the fractured limb with less post-operative complication than open reduction technique.

**Key words:** Dogs, Fracture, Modified ALPS, MIPO, ORIF, Tibia.

*Ind J Vet Sci and Biotech* (2025): 10.48165/ijvsbt.21.1.11

## Introduction

Bone fractures are considered as a significant issue for dogs due to the relative rise in pet ownership. After femur and radius/ulna fractures, tibial fractures are the third most frequent type of fracture and they account for about 20% of all long bone fractures (Seaman and Simpson, 2004). Diaphyseal fractures account for approximately 73% of all tibial fractures. Distal tibial fractures are less common, accounting for approximately 20% of all tibial fractures. Proximal tibial fractures are the least frequent (7%). Fibular fractures are frequently associated with tibia fractures (Seaman and Simpson, 2004). Transverse fractures had higher incidence followed by oblique and comminuted fractures (Kushwaha *et al*., 2011).

The Advanced Locking Plate System (ALPS) is a veterinary locking plate system. ALPS was developed based on research conducted on the point contact fixator (PCFix) at the AO Research Institute in Davos, Switzerland, with the primary goal of preserving blood supply. To achieve this, the plate's underside was shaped to make as little contact with the bone as possible (Guerrero *et al*., 2014). ALPS adheres to the principle of preserving the viability of bone fragments and soft tissue immediately deep into the plate by fusing two distinct features.

Department of Surgery & Radiology, Veterinary College, Bidar-585 226, Karnataka Veterinary, Animal and Fisheries Sciences University, India

**Corresponding Author:** Manjunath Patil, Associate Professor, Dept of Surgery & Radiology, Veterinary College, KVAFSU, Bidar-585226, India. e-mail: manjunathpatilvet@gmail.com

**How to cite this article:** Pooja, H. S., Desai, D., & Patil, M. (2025). Evaluation of Modified Advanced Locking Plate System by MIPO and ORIF Techniques for Tibial Fracture Repair in Dogs. Ind J Vet Sci and Biotech. 21(1), 52-57.

**Source of support:** Nil

**Conflict of interest**: None

**Submitted** 25/10/2024 **Accepted** 20/11/2024 **Published** 10/01/2025

Recently, a new method of bone plating has been developed called as minimally invasive plate osteosynthesis (MIPO). It was the method of biological internal fixation that involved placing a bone plate through small insertional incisions made far from the fracture site. In an epiperiosteal tunnel connecting the two insertional incisions, the plate was slid adjacent to the bone. Screws were inserted into the plate through the insertional incisions or through additional stab incisions made over the plate's holes. When using minimally invasive fracture fixation techniques, the precision of the surgical approach and knowledge of the local anatomy is

critical because the fracture site is never exposed, it is critical to understand the safe zones where implant insertion is possible (Pozzi and Lewis, 2009). This technique conforms to the principles of biological osteosynthesis because the fracture site is not exposed and the fracture haemtoma is only minimally disturbed. By minimising soft tissue damage and avoiding the fracture site haematoma, the MIPO technique safeguards the biological environment that promotes rapid bone healing (Istim and Arican, 2022). A search of literature revealed, dearth of information regarding the use of modified advanced locking plate system by minimally invasive plate osteosynthesis and open reduction and internal fixation techniques for tibial fracture repair in dogs, and hence was evaluated in this study.

## Materials and Methods

The study was conducted on 12 clinical cases of dogs (7 male and 5 females), aged 8-24 months, presented with the history of tibial bone fracture following car or bike accidents, or pig attack to the Department of Veterinary Surgery and Radiology, Veterinary College, Bidar (KVAFSU, India). Dogs were randomly divided into 2 groups, six dogs in each. Diagnosis of tibial fracture was made based on clinical and radiographic examination. Type and location of fracture were transverse mid diaphyseal (n=8), short oblique mid diaphyseal (n=3) and comminuted diaphyseal (n=1). In group I and II, dogs suffering from tibial fractures were treated with 3.5 mm modified 10 holes mALPS using 4 to 9 screws by minimally invasive plate osteosynthesis (MIPO), and open reduction with internal fixation (ORIF) techniques, respectively.

The animals were prepared following standard surgical protocol. Anaesthesia was induced by Atropine sulphate (0.045 mg/kg I/M) 10 min after Triflupromazine hydrochloride (1 mg/kg, I/V) was given, and 15 min later general anesthesia was induced with Thiopental sodium (12.50 mg/kg I/V). After intubation animals were maintained with Isoflurane 2 to 3%.

Medial surgical approach was used to perform MIPO of tibia (Guiot and Dejardin, 2020) by positioning the dog in lateral recumbency with fractured limb on the table. A 2-4 cm longitudinal incision was made over the medial aspect of the proximal tibia. The tendons of insertion of the sartorius, gracilis and semitendinosus muscles were incised and elevated. Medial aspect of the proximal tibia was exposed by caudal retraction of these muscles. A 2-3 cm skin incision was then made over the medial aspect of the distal tibia (Pozzi and Lewis, 2009). An epiperiosteal tunnel was created under the skin, carefully sparing the medial saphenous artery and vein using scissors from distal incision towards proximal incision.

After the limb alignment and the fracture reduction was assessed and considered satisfactory using C-arm, through the epiperiosteal tunnel the modified advance locking plate system was inserted through the distal incision and advanced along the medial surface of the tibia until the end of the plate was appropriately positioned. Proximal most hole of plate in proximal tibial segment was drilled and screw was then inserted into the proximal tibial fragment. The screws were tightened securely once the limb alignment and fracture reduction was considered satisfactory. At the end 2-3 screws were positioned in proximal and distal holes of plate. Additional locking screws were added through stab incisions in some cases. The proximal and the distal incisions were sutured using 2-0 polyamide.

A cranio-medial skin incision was made along most of the tibial length. The bone was exposed by incision of the crural fascia over the medial shaft of the tibia. Muscles were exposed by elevating the fascia. The cranial tibial and medial digital flexor muscles could be retracted by incising fascia along their borders to make them free from the bone. The fracture segments were identified and reduced. After satisfactory fracture reduction and limb alignment, the modified advanced locking bone plates were applied along the medial surface of the tibia using self centering bone holding forcep following AO/ASIF principles for plate fixation. Self-tapping locking cortical screws (3.5 mm) were inserted and were locked at locking hole of the bone plates using a 3.5 mm hexagonal screw driver. The muscles were sutured with simple continuous lock pattern using 2-0 poliglecaprone suture material followed by the closure of the incisional wound on the skin with vertical mattress suture pattern using 2-0 trulon.

The clinical evaluation of fracture healing was performed on pre-operative day, and post-operative day 0, $15^{th}$, $30^{th}$, $45^{th}$ and $60^{th}$ to assess the weight-bearing based on functional limb usage using the standard classification given by Fox *et al.* (1995). Also, post-operative lameness grading classification was assessed and categorized as Grade I to V using the classification given by Vasseur *et al.* (1995).

Four mL of blood was collected in clot activator vials on pre-operative, 0, $15^{th}$, $30^{th}$ and $60^{th}$ post-operative days in both the groups for estimation of serum calcium, inorganic phosphorus and alkaline phosphatase by using a biochemical analyser (ERBA-Mannheim make, Germany) and the diagnostic kits.

The radiographs were taken on post-operative days 0, $15^{th}$, $30^{th}$, $45^{th}$ and $60^{th}$ in both the groups. Based on the periodic radiographs - implant position, union of fragments and callus formation were studied. The fracture healing was evaluated and recorded through these radiographic signs. A radiographic scoring was carried out to each radiograph to evaluate the fracture healing as given by Cook *et al.* (1999).

In all cases, intra-operative and post-operative complications were examined and documented. The quantitative data such as physiological and biochemical parameters were analysed using student's 't' test, as outlined by Snedecor and Cochran (1994). Qualitative parameters were analysed by arbitrary score card method.

## Results and Discussion

### Clinical Evaluation

The primary aims of fracture treatment are to alleviate pain, achieve fracture healing and restore function to as near normal a level as possible according to Rob Pettitt (2016).

When compared to the dogs of group II (average 9.83 days), the dogs in group I showed early weight-bearing of the fractured limb during walking (average 3.67 days), because MIPO technique protects the biological environment that facilitates fast bone healing by minimizing soft tissue damage and avoiding the fracture site haematoma as documented by Istim and Arican (2022). Current results also concurred with reports of Marvania *et al*. (2020), who stated that MIPO technique allowed for earlier weight bearing than open plating.

### Functional Limb Usage and Grading of Lameness

With respect to functional limb usage of the dogs, in group I, all the dogs reached excellent grade by the end of day 60. Schmokel *et al*. (2007) documented patients returned to full limb function within two to three months. Baroncelli *et al*. (2012) reported the outcome of MIPO in eight dogs; all the dogs exhibited a excellent limb function by 30$^{th}$ post-operative day. Pozzi *et al*. (2012) proposed that dogs undergoing MIPO be evaluated within the first 2 to 3 weeks of surgery because fractures might be completely healed and dogs would be able to resume normal activity in less than one month.

In group II, four dogs achieved excellent grade, one dog reached good grade and another one dog showed fare grade. Baroncelli *et al*. (2012) reported the good limb function in dogs treated with open reduction technique at 30$^{th}$ post-operative day.

Post-operative lameness grading of dogs revealed that in group I, all the dogs reached a lameness grade of I by the end of day 60. In group II, four dogs reached a grade I lameness, one dog reached grade II lameness and one dog reached grade III lameness by the end of day 60. Good results seen in group I compared to the group II were due to the protection of biological environment at fracture site intra-operatively that facilitates rapid bone healing by minimizing soft tissue damage and avoiding the fracture site haematoma as documented by Istim and Arican (2022). Current results are in accordance with those documented by Marvania *et al*. (2020).

### Biochemical Evaluation

Biochemical parameters, *viz.,* Serum alkaline phosphatase, serum calcium and serum phosphorus before and after treatment in group I and II animals are recorded in Table 1.

In group I, mean value of serum alkaline phosphatase was highest on the pre-operative day, which concurred with result of Patil *et al*. (2017). The lowest concentration of serum alkaline phosphatase was recorded on the 30$^{th}$ post-operative day, followed by a slight increase in the concentration on the 60$^{th}$ post-operative day. In group II, mean value of serum alkaline phosphatase was highest on the day 15, which matched with result of Bhavani *et al*. (2022) and the lowest concentration of serum alkaline phosphatase was recorded on the 30$^{th}$ post-operative day, followed by a slight increase in the concentration on the 60$^{th}$ post-operative day. All the values recorded in the study appeared to be within the normal physiological range and in accordance with Ojus *et al*. (2022). The increased chondroblastic proliferation that occurs during fracture repair, and the maximum contribution from the periosteum of destroyed bone - a rich source of serum alkaline phosphatase - are the two factors that contribute to the increase in serum alkaline phosphatase levels as documented by Hegade *et al*. (2007).

In both the groups, a gradual increase in the concentration of mean serum calcium value was observed from the pre-operative day up to the 15$^{th}$ post-operative day, which was followed by gradual decrease in concentration till the 60$^{th}$ post-operative day. The highest values were observed on the 15$^{th}$ post-operative day in both the groups, although within the normal physiological range. These results were in accordance with Bhavani *et al*. (2022). The increased levels of serum calcium from the pre-operative day to the 15$^{th}$ post-operative days of fracture healing could be due to increased osteoclastic activity at the fracture site, which leads to resorption of dead bone according to the Ojus *et al*. (2022). In contrary to that Chaurasia *et al*. (2019) recorded significantly ($p \leq 0.05$) lower serum calcium on the 15$^{th}$ post-operative day than on the other post-operative days. According to Souza *et al*. (2011), the level of serum calcium increased on day 60 and then started to decline on day 90.

**Table 1:** Mean ± SE values of biochemical parameters before and after treatment in dogs of group I and II

| Biochemical parameters | Groups | Preoperative | Day 0 | Day 15 | Day 30 | Day 60 |
|---|---|---|---|---|---|---|
| Serum Alkaline Phosphatase (IU/L) | Group I | 115.33±1.12$^{a}$ | 102.50±1.18**$^{a}$ | 93.33±0.67**$^{a}$ | 83.50±0.847**$^{a}$ | 94.17±1.30**$^{a}$ |
| | Group II | 94.17±1.17$^{b}$ | 81.33±0.42**$^{b}$ | 97.33±0.71*$^{b}$ | 76.67±0.67**$^{b}$ | 83.83±1.01**$^{b}$ |
| Serum Calcium (mg/dL) | Group I | 9.49±0.76$^{a}$ | 9.92±0.01** | 10.40±0.02**$^{a}$ | 9.51±0.04$^{a}$ | 9.03±0.01**$^{a}$ |
| | Group II | 9.18±0.05$^{b}$ | 9.84±0.07** | 11.26±0.05**$^{b}$ | 10.69±0.05**$^{b}$ | 10.26±0.09**$^{b}$ |
| Serum Phosphorus (mg/dL) | Group I | 3.15±0.01$^{a}$ | 3.47±0.02**$^{a}$ | 4.15±0.06**$^{a}$ | 4.86±0.01**$^{a}$ | 4.23±0.01**$^{a}$ |
| | Group II | 4.55±0.01$^{b}$ | 4.92±0.01**$^{b}$ | 5.36±0.04**$^{b}$ | 5.61±0.02**$^{b}$ | 4.52±0.01$^{b}$ |

Means with the superscript * and **differ significantly at $p \leq 0.05$ and $p \leq 0.01$, respectively, from pre-operative to different post-operative intervals within the group. Means with superscript $^{a,b}$ differ significantly at $p \leq 0.05$ between the groups at corresponding intervals.

In both the groups, the mean values of serum phosphorus gradually elevated from the pre-operative day up to the 30$^{th}$ post-operative day, after which, the concentration gradually diminished till the 60$^{th}$ post-operative day. The highest values were achieved on the 30$^{th}$ post-operative day in both the groups. All the values recorded were within the normal physiological range. Osteoclastic activity at the fracture site that results in the resorption of dead bone could be the cause of the gradually declining serum phosphorus concentration according to Komnenou *et al.* (2005). The present results lined up with documentation of Ojus *et al.* (2022). However, Hegade *et al.* (2007) noted elevated serum inorganic phosphorus levels on all the post-operative days compared to the operative day. Reddy (2021) reported lowest serum phosphorus values on the pre-operative day, gradually increased up to the 60$^{th}$ post-operative day, and then decreased to normal physiological limits in all groups of dogs.

## Radiographic Evaluation

Radiological scoring in dogs of group I and group II are recorded in Figure 1 and 2. In group I, post-operative 15$^{th}$ day radiographs depicted the appropriate alignment of fracture fragments in all the six dogs. Sharpness at the fracture edges was lost in radiographs. Mild periosteal callus formation was seen in 4 out of six dogs, which was in accordance to the results of Daniella (2017). Radiolucent fracture line was clearly visible in all the cases in accordance to Sharanya (2014).

Post-operative 30$^{th}$ day radiographs revealed the good bridging callus formation at the fracture site in all the cases. Radiolucent fracture line was faintly visible in all the cases. Present results were in agreement with Sharanya (2014). Periosteal callus appreciated in four cases. According to the Baroncelli *et al.* (2012), clinical union was defined as presence of bridging callus or 50% of tibial diameter at the level of fracture site on three of four cortices on two orthogonal views and they observed clinical union in 30 days in 5 dogs out of 8 dogs.

On the 45$^{th}$ post-operative day, the radiographic evaluation revealed, slow obliteration of the fracture line with the bony callus bridging the fracture area. Callus appears opaque like a normal bone. In 2 cases, fracture line was not visible completely in radiograph with radiographic score of zero. Reduction in the fracture gap noticed in all the six dogs. Present results were in agreement with Sharanya (2014). Schmokel *et al.* (2007) observed advanced bony healing with callus formation and filling of the fracture gaps with calcified tissue in all radiographed animals by the end of sixth weeks. On the post-operative 60$^{th}$ day radiographs, complete radiographic healing noticed in four dogs with


**Fig. 1:** Sequential medio-lateral radiographs of Group I of pre-operative, post-operative day 0, 15$^{th}$, 30$^{th}$, 45$^{th}$ and 60$^{th}$ showing the repair of complete transverse mid diaphyseal fracture of tibia with MIPO technique.


**Fig. 2:** Sequential medio-lateral radiographs of Group II of pre-operative, post-operative day 0, 15$^{th}$, 30$^{th}$, 45$^{th}$ and 60$^{th}$ showing the repair of complete transverse mid diaphyseal fracture of tibia with ORIF technique.

complete absence of fracture line in radiograph. These findings corroborated with Sharanya (2014). Townsend and Lewis (2018) observed union by 10 weeks in all the dogs.

In group II, immediate post-operative day 0 radiographic evaluation confirmed the proper placement of modified advanced locking plate system and screws at the medial aspect of tibia and correct apposition and alignment of the fracture fragments in all the six dogs. On the post-operative 15$^{th}$ day radiographs, appropriate alignment of the fracture fragments and stability of fracture fragment was good in all the cases with exception of one case, where plate bending was seen on 5$^{th}$ post-operative day. Loss of sharpness at the fracture edges was visible in the radiographs. Poor callus formation was seen in three dogs. Radiolucent fracture line was clearly visible in all the cases. Post-operative 30$^{th}$ day radiographs revealed good callus formation in three cases and moderate callus formation in two cases. The stability of implant and fracture fragments were found to be satisfactory in five dogs. Bridging callus at the fracture line was noted in five out of six dogs. Periosteal callus noticed in few cases.

On the post-operative 45$^{th}$ day, the radiographic evaluation revealed, slow obliteration of the fractured line with the bony callus bridging the fracture area. Callus appeared opaque like a normal bone. Radiolucent fracture line started to faint in radiographs. Good callus formation was noticed in all the five cases. Post-operative 60$^{th}$ day radiographs depicted good progression of callus formation towards bone healing in five out of six dogs. Implant and fracture fragments were stable in the five cases. According to the Baroncelli *et al*. (2012), clinical union achieved in 60 days in 5 out of 8 dogs, which were treated with open reduction technique. Pozzi *et al*. (2012) recorded healed fractures radiographically by the period of 56 to 80 days in all the dogs. According to Kowaleski (2012), due to minimal disruption of the local blood supply and preservation of soft tissue structure, MIPO had a faster rate of healing than open reduction technique.

### Intra-Operative and Post-Operative Complications

No intra-operative complications were noticed in study period, which was due to precise and good quality instrumentation, combined with good surgical skill. Similarly, no post-operative complication was observed in any of the dogs in group I, while in group II, plate bending was observed in one dog out of six dogs on 5$^{th}$ post-operative day since the dog was very aggressive. The following day, the corrective procedure was carried out and replating was accomplished using a 3.5 mm modified advanced locking plate system through open reduction technique. Similar complication was observed by Marvania *et al*. (2020). Sharma *et al*. (2006) noticed plate bending in their study and stated that fatigue failure is main reason for plate failure. Wound dehiscence was observed in two cases (Case 1 and Case 6) of group II due to infection at the suture site, which concurred with Marvania *et al*. (2020).

## Conclusion

Based on clinical, biochemical and radiological evaluation, it was concluded that, modified ALPS provided satisfactory results when applied for the repair of diaphyseal fractures of tibia in dogs, offering good stability of the fracture fragments and consistently good functional outcomes. For routine clinical application, the minimally invasive plate osteosynthesis procedure was technically demanding and necessitated additional skill. Early weight bearing during rest and/or walking was witnessed in MIPO as compared to open reduction technique. Biochemical evaluation revealed serum values of calcium, phosphorus and alkaline phosphatase differed significantly between the groups. Also, on post-operative radiological evaluation, complete bone healing appreciated early in MIPO compared to open reduction technique. Post-operative complication in wound healing was noticed in open reduction, whereas, in MIPO surgical wound healed within 10 days without complications.

## Acknowledgement

Authors would like to acknowledge the Dean, Veterinary College, Bidar for financial assistance in conducting this research.

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