RESEARCH ARTICLE

Evaluation of Tie-In Fixator Technique for Tibial Fracture Repair in Domesticated Rabbits

Braganca Pereira Esther Maria[1], Dilipkumar Desai[1], Manjunath Patil[2]*, Vijay Kumar[3]

Abstract

The study was conducted on 12 clinical cases of rabbits with tibial fractures divided into two groups consisting of six rabbits in each group. The fractures were repaired using tie-in fixation (TIF) with a PMMA connector bar through open reduction retrograde approach (group I) and closed reduction normograde approach (C-arm guided) (group II). Following fracture repair, the rabbits were evaluated for fracture healing on the 15th, 30th, 45th and 60th day on the basis of a clinical evaluation, lameness grading, radiographic and biochemical profile. Most of the rabbits exhibited normal hopping gait by day 60 with few complications. Radiographic evaluation revealed adequate callus formation and progressive fracture healing. Biochemical evaluation showed a fluctuating trend in values of serum calcium, phosphorus and AKP within physiological limits. In conclusion, The TIF technique was suitable for repair of comminuted, oblique and transverse tibial fractures and resulted in early ambulation in domesticated rabbits.

Keywords: Fracture healing, Tibia bone fracture, Tie-in fixator, Rabbits.

Ind J Vet Sci and Biotech (2026): 10.48165/ijvsbt.22.5.22

Introduction

Long bone fractures, account for more than 50% of reported fractures in rabbits (*Oryctolagus cuniculus)*, often caused by fall injuries or while jumping from owners' arms compared to fractures in cats and dogs that are typically the result of high-impact trauma, like automobile accidents or bite wounds. Rabbits have a smaller bone to body weight ratio, with nearly 70% of their body weight in their hind limbs with highly muscled pelvic limbs potentially contributing to the higher prevalence of tibial and femur fracture than forelimb fractures. A strong startle response and high sensitivity to perceived threats make this species vulnerable to falls, resulting in fractured bones (Davolt *et al.,* 2022).

In veterinary medicine, external fixation is widely used for fracture repair, joint stabilization, and extremity deformations. The benefits of this approach include its adaptable configuration, the potential to manage wound in open fractures, safeguarding vascularization along the fracture line, and its cost-effectiveness (White *et al.,* 2003). ESF eliminates bending, rotational, and shearing forces, maintains fracture apposition, with minimal damage to soft tissue and vasculature, avoids fracture site implants, allows accessibility of wounds for soft tissue wound management, is relatively low cost, and easy to apply. The tie-in-fixator (TIF) or hybrid external fixator consists of the external union of the IMP with the ESF pins, either by a long IMP bent 90° twice, to make it run parallel to the affected bone externally, or with a connecting bar (Miwa and Carrasco, 2019). The advantage of applying the type Ia external fixator laterally in rabbits was avoiding interference with the body wall however the drawback was the large musculature and the fibula (Mammal and Kapatkin, 2020).

Acrylic ESFs outperform other types of ESF in terms of cost-effectiveness. They offer greater flexibility in the placement of fixation pins since alignment in a single longitudinal plane is not necessary. The use of fixation pins of varying diameters, their lightweight nature and radiolucency contribute to their advantages. Furthermore, in acrylic ESF, the accommodation of a misdirected pin is possible by altering the shape of the acrylic column (Oezak *et al.,* 2009). This study was conducted on clinical cases of rabbits with tibial fractures to evaluate tie-in fixator technique and record

[1]Department of Veterinary Surgery and Radiology, Veterinary College, Bidar-585226, Karnataka Veterinary, Animal and Fisheries Sciences University, Karnataka, India

[2]Department of Veterinary Clinical Complex, Veterinary College, Koila-574241 (Dakshina Kannada), KVAFSU, Karnataka, India

[3]Department of Veterinary Clinical Complex, Veterinary College, Bidar-585226, KVAFSU, Karnataka, India

Corresponding Author: Dr. Manjunath Patil, Professor & Head, Department of Veterinary Clinical Complex, Veterinary College, Koila-574241 (Dakshina Kannada), KVAFSU, Karnataka, India. E-mail: manjunathpatilvet@gmail.com

How to cite this article: Esther Maria, B. P., Dilipkumar D., Patil, M., & Kumar, V. (2026). Evaluation of Tie-In Fixator Technique for Tibial Fracture Repair in Domesticated Rabbits. Ind J Vet Sci and Biotech, 22(5), 116-122.

Source of support: Nil

Conflict of interest: None

Submitted 08/06/2026 **Accepted** 28/07/2026 **Published** 10/09/2026

© The Author(s). 2026 Open Access This work is licensed under a Creative Commons Attribution-Non Commercial-No Derivatives 4.0 International License.

radiological and biochemical changes before and after fracture repair in domesticated rabbits.

Materials and Methods

The present clinical study was conducted on 12 domesticated rabbits with tibial fractures, presented to the Department of Veterinary Surgery and Radiology, Veterinary College, Bidar (Karnataka, India). This clinical study acquired approval from the Institutional Animal Ethics Committee (IAEC) of Veterinary College, Bidar (No.: VCB/IAEC/VSR 1/2023-24 dated 13-01-2024). In addition, an informed consent form was obtained from the owner of each animal. Routine clinical, physical, orthopedic, and radiographic examinations were performed to diagnose tibial fractures in all cases.

The selected confirmed tibial fractures cases (n=12) were divided into two groups, irrespective of their age, breed, sex, or weight. Tibial fractures in this study were treated using a tie-in fixation technique, either by open reduction retrograde approach (group I) or C-arm guided normograde approach (group II) depending on type of fracture. The cases presented for tibial fractures were primarily subjected to clinical evaluation. In present study, out of 12 rabbits 10 were New Zealand White breed and two were of Dutch breed, out of which eight were males and four were females. The age of the rabbits ranged from 1 to 4 years. With regard to the aetiology of fractures, mongoose attacks (41.67%) were the major cause of fractures followed by legs stuck in cages (25.00%), dog bite injuries (16.67%), chased by cats (8.33%) and crush injury by human foot (8.33%).

The rabbits were physically examined for swelling, pain, loss of limb function, weight bearing capacity, abnormal gait, change in angulation of the affected limb and crepitation at the fracture site (DeCamp, 2015). The rabbits were also evaluated for any neurological deficits. The fractures were temporarily immobilized using a wooden splint (ice-cream stick), cotton padding and bandaged using cohesive vet wrap until the day of surgery. After initial clinical assessment, pre-operative radiographs of the fracture site were taken in two views orthogonal to each other under sedation. Cranio-caudal and medio-lateral radiographs including the adjacent joints were obtained (Helmer and Lightfoot, 2002).

Measurements of the contralateral tibia were obtained from the pre-operative radiographs. The narrowest medullary cavity diameter of the bone was used to select the diameter of the intramedullary K-wire in cranio-caudal view. The length of intramedullary K-wire and diameter of the trans-cortical K-wires was determined by measuring the bone length and bone diameter of the contralateral tibia in the medio-lateral view at different distances from the fracture site.

Prior to planning the surgical orthopedic repair, careful consideration was given to the rabbit's physiology, response to pain, and predisposition for post-operative gastrointestinal stasis (Rich, 2002). All animals were kept off feed and water for 2 h prior to surgery (Gardhouse and Sanchez, 2022). The cephalic vein was prepared for intravenous fixation of scalp vein catheter of 24/26 gauge and normal saline was infused intravenously throughout the surgery. Injection Enrofloxacin (10 mg/kg b.wt.) and injection Meloxicam (0.50 mg/kg b.wt.) were administered subcutaneously, 30 min prior to surgery.

The rabbits in both groups were pre-anesthetized with Inj. Glycopyrrolate (0.01 mg/kg b.wt.) 10 min prior to Inj. Xylazine (3 mg/kg b.wt.), intramuscularly. Anaesthetic protocol in group I included Inj. Ketamine HCl (15 mg/kg b.wt.) and Midazolam (0.20 mg/kg b.wt.) as a mixture intramuscularly, while in group II Inj. Tiletamine-Zolazepam (1:1 ratio) was used @ 15 mg/kg b.wt. intramuscularly. As soon as the righting reflex was lost, the rabbits in both groups were placed in prone position with head and neck extended and V-gel inserted after applying Lignocaine HCl 2% jelly. The position of V gel was confirmed by observing the movement of rebreathing bag. The connector was connected to Mapleson F circuit. Immediately after insertion of V-gel in rabbits of both groups, 100% oxygen was administered at the flow rate of 0.80 L/min. The isoflurane vaporizer setting was adjusted at 1-3% to maintain a surgical plane of anesthesia. The tie-fixation technique in rabbits of both groups was carried out under isoflurane maintenance.

After completion of surgical procedure, administration of isoflurane was stopped and oxygen (100%) at flow rate of 0.80 L/min was administered until restoration of swallowing reflex. The anaesthetic circuit was disconnected, and V-gel removed. After that the animal was maintained with face mask on 100% oxygen at 2 L/min for 10-15 minutes.

Retrograde Surgical Approach to the Tibia in Group I

Intramedullary pin insertion: The fractured site was palpated, and a 2 cm longitudinal skin incision was made on the medial aspect of the tibia at the level of the fracture for retrograde insertion of K-wire. The fracture fragments were exposed. The diameter of the K-wire used was 40-50% depending on individual case of the bone's medullary cavity diameter at the narrowest point (Aydin *et al.,* 2022) assessed prior to surgery by radiography of the contralateral limb. Following insertion of intramedullary K-wire, the skin was sutured in a single layer in simple interrupted pattern using 3-0 monofilament polydioxanone suture material.

Transcortical (Type I ESF) pin insertion technique: For transcortical K-wire insertion, the K-wires were inserted from the lateral aspect of tibia (Langley-Hobbs and Harcourt-Brown, 2013). The diameter of the transcortical K-wires were assessed prior to surgery by radiography of the contralateral limb. The diameters of the K-wires were 20 to 25% of the bone diameter depending on individual cases. Transcortical K-wire diameters of 0.8 mm, 1.0 mm and 1.2 mm were used. The external portion of the intramedullary K-wire was inserted into a flexible PVC tube. On the lateral aspect of tibia, stab incisions were made through the skin over the proximal and distal fragment. The soft tissue was cleared by blunt dissection to expose the bone. Using an electric power driller, one transcortical K wire was drilled in the proximal

fragment and two transcortical K-wires were drilled in the distal fragment until they exited the trans-cortex.

Connector bar with PMMA: The transcortical K-wires and externally bent K-wire were connected by a flexible PVC tube filled with PMMA (acrylic). The self-cure acrylic powder and liquid were mixed in a 2:1 ratio. The acrylic mixture in a semi-solid state was infused rapidly with a 10 mL syringe into the PVC tube as it started solidifying within 30-60 seconds. After complete hardening of acrylic, excess parts of the transcortical K-wires were cut close to the acrylic bar. These bars were positioned 0.50 cm away from the skin to reduce the working length of transcortical K-wires. The surface of the skin between the connector bar and K-wire-skin interface was covered with sterile roller gauze. The exothermic reaction lasted for about 5 min and was neutralized by pouring cool sterile normal saline over the roller gauze.

Normograde Surgical Approach to the Tibia using C-arm in Group II

For normograde insertion of intramedullary K-wire, a stab incision was made lateral to straight patellar ligament to ensure the K-wire misses the joint (Langley-Hobbs and Harcourt-Brown, 2013) followed by blunt dissection of surrounding soft tissues. Through the stab incision, the entry point for the K-wire into the medullary canal was created by the sharp end of the pin as it was introduced in a normograde direction using Jacob's chuck. The K-wire was progressed into the medullary cavity which was confirmed using C-arm visualization. After manual reduction of fracture fragments, the K-wire was further progressed into the distal fragment and seated adequately into the distal epiphysis (Kaur *et al.,* 2015), utilizing the C-arm to confirm the entry of the K-wire into the distal fragment.

The protruding portion of the intramedullary K-wire was bent and directed parallel to the long axis of the tibia with the external portion inserted into a flexible PVC pipe as described before. After stab incisions were made laterally through the skin and blunt dissection of soft tissue, using a battery power driller one transcortical K-wire was drilled in the proximal fragment and two transcortical K-wires were drilled in the distal fragment until they exited the trans-cortex. The alignment of the fractured fragments and insertion of transcortical K-wires was confirmed using C-arm. This was followed by filling the PVC tube with PMMA, covering the skin-K-wire interface with sterile gauze soaked with normal saline which was removed after the tube had cooled down and hardened.

Post-Operative Management

The operated site was cleaned with dilute povidone iodine followed by application of topical Mupirocin ointment and then bandaged. In all animals, daily dressing was done up to 7 days followed by alternate day dressing until the sutures were removed on the 15th day post-operatively. Inj. Amoxicillin-sulbactam (10 mg/kg b.wt.) was administered intramuscularly once a day for 3 days along with suspension Enrofloxacin (10 mg/kg b. wt.) once a day orally for 7 days post-operatively. Inj. Meloxicam (0.50 mg/kg b. wt.) was administered subcutaneously once a day for 3 days followed by orally for another 5 days. Inj. Buprenorphine (0.02 mg/kg b. wt.) was administered intramuscularly twice a day for 3 days. Suspension Metoclopramide (0.50 mg/kg b. wt.) was administered twice a day orally for 5 days. Owners were advised to provide cage rest for the first 4 weeks post-operatively and then gradually allow some activity for short periods during the day. Owners were also advised to use an Elizabethan collar for the rabbits, to prevent self-mutilation.

Evaluation of Fracture Healing

Clinical evaluation: It was performed every day for the first two weeks post-operatively to check for the presence of swelling and exudate. The rabbits were examined on the 15th, 30th, 45th and 60th day post-operatively for evaluation of limb stability, weight bearing and fracture healing. Lameness grading was carried out on pre-operative day and post-operatively on 0th (immediate), 15th, 30th, 45th and 60th day as recommended by Von der Ahe *et al.* (2023).

Radiographic evaluation*:* Radiographs of the fractured tibia were taken in cranio-caudal and medio-lateral views including the adjacent joints post-operatively on the 15th, 30th, 45th and 60th day. The radiographic evaluation of fracture healing was done based on the pneumonic AAAA, *i.e.,* Alignment, Apposition, Apparatus and Activity as recommended by Piermattei and Flo (1997). Radiological scoring for fracture healing was done according to Tunio *et al.* (2014) using score 0, 1 or 2 for the bone union, fracture line and callus formation. Intra-operative and post-operative complications, if any, were recorded.

Biochemical evaluation: Blood samples were collected in clot activator vials pre-operatively on the 0th day and post-operatively on the 15th, 30th and 60th day and the serum was separated. In both groups, serum calcium, serum phosphorus and serum alkaline phosphatase levels were estimated by using semi-automatic biochemical analyzer (ARTOS make) with the kit supplied by Swemed diagnostics, Bengaluru and fracture healing was assessed.

Implant Removal

The implants were removed after complete fracture healing, confirmed by clinical and radiological evaluation at 6 weeks (45th day post-operatively). The PMMA fixator and K-wires were removed by cutting the transcortical K-wires between the PMMA connector bar and the skin with a pin cutter. The transcortical and intramedullary K-wires were removed using a Jacobs chuck. Subsequently, the pin tracts were cleaned with povidone iodine solution and Mupirocin ointment was applied topically.

Statistical analysis

The data obtained was tabulated and statistically analyzed using student's t-test as outlined by Snedecor and Cochran (1994), and expressed as Mean ± SE where n=6. A significant difference at p≤0.01 and p≤0.05 was considered.

Results and Discussion

Post-Operative Clinical Evaluation of Fracture Healing

Clinical evaluation was performed on 0th, 15th, 30th, 45th and 60th post-operative days. In retrograde approach, four rabbits attained good alignment of the fractured fragments and use of limb whereas two rabbits displayed slight stiffness of the limb while in sitting posture at day 60. In normograde (c-arm guided) approach, healing proceeded uneventfully in five rabbits, with one rabbit showing signs of medial deviation attributed to malunion. Most of the rabbits were able to use the limb normally during ambulation after fixator removal. This aligned with the observations made by Pead and Carmichael (1989). This positive outcome might be attributed to early mobilization, which led to enhanced blood supply in the fractured region, consequently resulting in improved fracture healing, according to Peirone *et al.* (2012). In an investigation carried out by Sasai *et al.* (2018), there was no significant disparity in the time required for healing between closed and open fractures. Consequently, they deemed ESF as a satisfactory approach for the treatment of open tibial fractures.

Lameness Grading

Lameness grading mean scores/grades for group I and II rabbits are presented in Table 1. Rabbits exhibited a noteworthy improvement in weight-bearing and a reduction in lameness during the post-operative period compared to the pre-operative phase. The assessment of lameness followed the grading system proposed by Von der Ahe *et al.* (2023). The results in the present study revealed that, eight rabbits achieved lameness Grade 0 during the period of study with three rabbits showed lameness Grade 1 due to slight stiffness of the limb and remaining one showed lameness Grade 1 due to malunion. The early return to function might be attributed to the high success rate of tie-in fixation in healing long bone fractures in rabbits with minimal impact on their behaviour as quoted by Sasai *et al.* (2018) and Aydin *et al.* (2022).

Radiographic Evaluation of Fracture Healing

A radiological examination was performed to confirm the type and location of the fractures. Out of 12 rabbits, 3 were simple and 9 were compound. Also, 8 had mid diaphyseal fractures and 4 had distal diaphyseal fractures. Radiological Scoring in rabbits of group I and group II is presented in Table 2. Pre-operative and post-operative radiographs were taken on the 0th, 15th, 30th, 45th and 60th day to assess the correct apposition and alignment of fracture fragments, callus formation and stability of implant which revealed adequate callus formation and progression towards fracture healing for group I (Fig. 1) and group II (Fig. 2), respectively.

As with external skeletal fixation, all fractures in the present study which can be seen in the post-operative radiographs resulted in secondary (indirect) bone healing. This could be due to the inability to achieve inter fragmentary compression as stated by Corr (2005). The author also opined that a certain level of axial micromotion was advantageous in creating beneficial strains across the fracture gap. Callus formation was visible around day 15 post-operatively in the present study. Comparable findings were also documented by Kamran *et al.* (2009) in rabbits at 3 weeks following fracture stabilization. The radiographic assessment of fracture healing revealed bridging periosteal callus formation, indistinct fracture lines, axial alignment, and slight cortico-medullary remodeling by 6 weeks in both the groups stabilized with

Table 1: Lameness grading for group I and II rabbits (Mean ± SE, n=6 each)

Group	Pre-op	PO day 0	Day 15	Day 30	Day 45	Day 60
Gr-I	4.00±0.00	4.00±0.00	2.83±0.17**	2.33±0.21**	1.17±0.17**	0.33±0.21**
Gr-II	4.00±0.00	4.00±0.00	3.00±0.26*	2.50±0.22**	1.67±0.33**	0.33±0.21**

Means with the superscripts *(p≤0.05) or **(p≤0.01) differ significantly from pre-operative to different post-operative intervals within the group.

Table 2: Radiological Scoring in rabbits of group I and group II

Criteria	Groups	0th day	15th day	30th day	45th day	60th day
Bone union	I	0.00 ±0.00	1.00 ±0.00**	1.00 ±0.00**	1.00 ±0.00**	1.00 ±0.00**
	II	0.00 ±0.00	1.00 ±0.00**	1.00 ±0.00**	1.00 ±0.00**	1.00 ±0.00**
Fracture line	I	0.00 ±0.00	0.33 ±0.21	1.00 ±0.00**	1.33 ±0.21**a	1.83 ±0.17**
	II	0.00 ±0.00	0.67 ±0.21*	1.00 ±0.00**	2.00±0.00**b	2.00 ±0.00**
Callus formation	I	0.00 ±0.00	1.00 ±0.00**	1.67 ±0.21**	2.00 ±0.00**	1.83 ±0.17**
	II	0.00 ±0.00	1.00 ±0.00**	1.83 ±0.17**	1.67 ±0.21**	1.67 ±0.21**

Means with the superscripts *(p≤0.05) or **(p≤0.01) differ significantly from day 0 to different post-operative intervals within the group. Means with superscripts (^{a,b}) differ significantly (p≤0.05) between the groups at corresponding intervals.

acrylic tie-in fixation. This aligned with the findings of Jeon *et al.* (2020). Piermattei and Flo (1997) stated that the abundance of callus formation was not from instability however rather a response of periosteal blood supply and formation of new bone in relation to severity of fracture.

Comparison between the groups revealed a significant difference ($p \leq 0.01$) in radiological scoring of bone union at different intervals of the study, a significant difference ($p \leq 0.01$) at day 0 and 30 and a significant difference ($p \leq 0.05$) at day 45 in radiological scoring of fracture line and a significant difference ($p \leq 0.01$) in radiological scoring of callus formation at day 0 and day 15. According to Bueno *et al.* (2015), fractures treated through closed surgical reduction were likely to heal more rapidly compared to those managed by open surgical reduction. This was attributed to the lesser extent of soft tissue damage, consequently reducing the risk of additional complications.

Biochemical Evaluation of Fracture Healing

Mean ± SE values of biochemical parameters on different post-operative days in rabbits of group I and group II are presented in Table 3. In both groups, serum calcium levels revealed a gradual rise from the pre-operative day to the 30th post operative day, followed by a decline to the baseline value on the 60th post-operative day. Comparison between the groups revealed a significant difference ($p \leq 0.05$) on the 15th day post-operatively. The increased levels of serum calcium could be attributed to an increase in osteoclastic activity at the site of the fracture, resulting in the absorption of necrotic bone tissue. Subsequently, the gradual decrease might be attributed to a reduction in the concentration of calcium in the extracellular space, thereby triggering the release of hormones involved in calcium metabolism, as reported by Komnenou *et al.* (2005).

Analysis of serum phosphorus and alkaline phosphatase (ALP) levels revealed a significant increase in serum phosphorus and ALP levels at day 15 in both groups, followed by a decline until the 60th post-operative day. However, all the values fluctuated within normal physiological limits. The increase in concentration of serum phosphorous could potentially be attributed to the osteoclastic activity occurring at the site of the fracture, resulting in the resorption of necrotic bone and release of stored phosphorus into the blood stream as documented by Anaraki *et al.* (2021). Increased levels of serum alkaline phosphatase (ALP) during fracture healing serves as a marker for bone formation, suggesting elevated osteoblast activity and accelerated process of healing (Anaraki *et al.,* 2021).

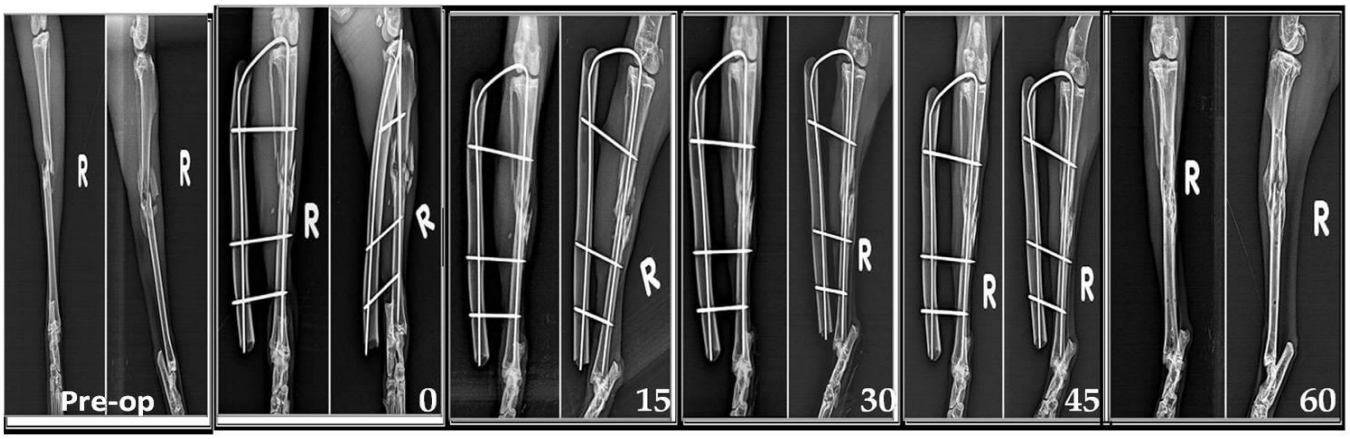


Fig. 1: Sequential radiographs of cranio-caudal and medio-lateral views of Group I, Case 4 of pre-operative, post-operative 0, 15th, 30th, 45th and 60th day showing the repair of comminuted mid diaphyseal tibial fracture with open reduction retrograde approach.

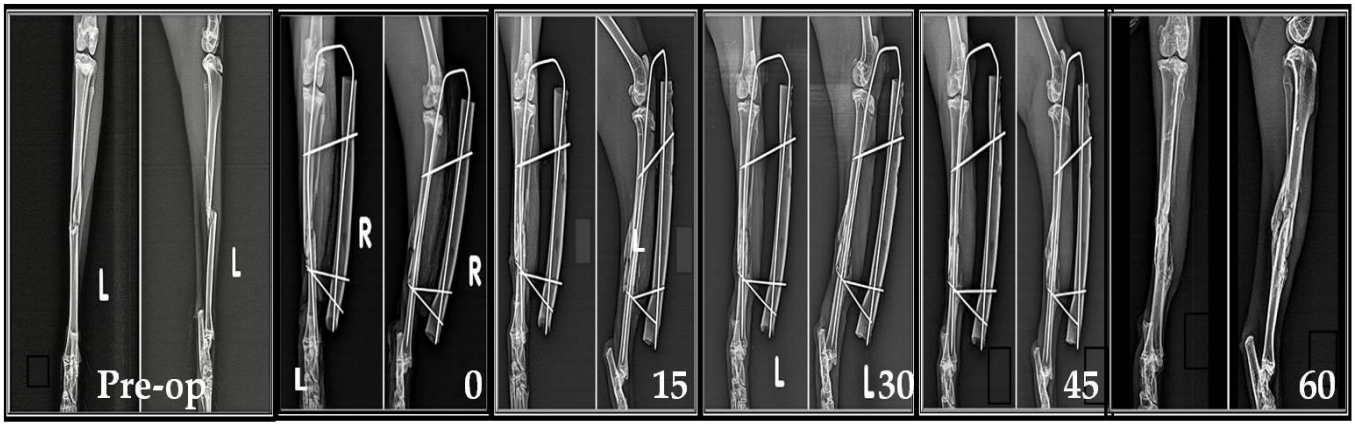


Fig. 2: Sequential radiographs of cranio-caudal and medio-lateral views of Group II, Case 2 of pre-operative, post-operative 0, 15th, 30th, 45th and 60th day showing the repair of comminuted mid diaphyseal tibial fracture with closed reduction normograde approach (C-arm guided).

Table 3: Mean ± SE of biochemical parameters on different days in rabbits of group I and II

Parameter	Group	Pre-operative	15th Day	30th Day	60th Day
Serum calcium (mg/dL)	I	10.56±0.25	12.63±0.23^{**a}	13.19±0.19**	11.07±0.17
	II	10.10±0.10	11.89±0.10^{**b}	12.80±0.09**	10.75±0.21
Serum phosphorus (md/dL)	I	4.72 ± 0.11	6.20 ± 0.10**	5.91 ± 0.09**	4.78 ± 0.11
	II	4.46 ± 0.08	6.00 ± 0.13**	5.60 ± 0.12**	4.55 ± 0.06
Serum ALP (IU/L)	I	45.19 ± 0.72^{a}	96.05 ± 1.91**	89.46± 0.95**	48.06 ± 1.23
	II	42.35 ± 0.59^{b}	93.18±0.62**	86.43± 1.29**	45.05 ± 1.12

Means with the superscripts *(p≤0.05) or **(p≤0.01) differ significantly from day 0 to different post-operative intervals within the group. Means with superscripts (^{a,b}) differ significantly (p≤0.05) between the groups at corresponding intervals

The implants were taken out after 6 weeks based on clinical assessment indicating absence of movement and pain at the fracture site, along with radiographic evaluation revealing consistent density of bridging callus with smooth edges, diminished visibility of the fracture line, and stable implants in all rabbits. The average weight of the implant was 7.47 ± 0.08 grams which was lightweight and resulted in better adaptability and earlier weight bearing.

Intra-operative complications such as misdirection of the intramedullary K-wire in group II animals operated through closed reduction guided by C-arm were observed. Post-operative complications such as localized pin tract infections at the intramedullary pin-skin interface, malunion at the fracture site due to loosened transcortical K-wire and knuckling that resolved after removal of fixator were observed.

Conclusion

Based on the above findings, it was concluded that tie-in fixation yielded favourable outcomes when applied for the repair of comminuted, oblique and transverse tibial fractures in rabbits offering rapid and good stability of fractured fragments and resulted in early ambulation. Radiologically, all rabbits showed callus formation and good progression towards healing during the period of study with the exception of one rabbit with a malunion. Biochemical evaluation revealed serum values differed significantly between the groups, whereas all the values were within physiological limits.

Acknowledgement

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

References

Anaraki, N., Beyraghi, A.H., Raisi, A., Davoodi, F., Farjanikish, G., & Sadegh, A.B. (2021). The effect of aqueous extract of *Prunus dulcis* on tibial bone healing in the rabbit. *Journal of Orthopaedic Surgery and Research, 16*(1), 1-11.

Aydin, U., Özaydin, İ., Aksoy, Ö., Ermutlu, C.Ş., Kilic, E., Yildiz, U., & Tanriverdi, E. (2022). Clinical and radiological evaluation of tie-in osteosynthesis with intramedullary threaded pin in diaphyseal humeral, tibial, and femoral fractures in dogs. *Journal of the Faculty of Veterinary Medicine Kafkas University, 28*(5)*, 593-599.*

Bueno, I., Redig, P.T., & Rendahl, A.K. (2015). External skeletal fixator intramedullary pin tie-in for the repair of tibiotarsal fractures in raptors: 37 cases (1995-2011). *Journal of the American Veterinary Medical Association, 247*(10)*,* 1154-1160.

Corr, S. (2005). Practical guide to linear external skeletal fixation in small animals. *In Practice, 27*(2)*,* 76-85.

Davolt, M.L., Davis, E., McCleery, B., & Davis, G. (2022). Biomechanical analysis of 3 fixation techniques in rabbit radius and humerus bones. *Canadian Veterinary Journal, 63*(5)*,* 521-527.

DeCamp, C.E. (2015). Fractures: Classification, diagnosis, and *treatment. In: Handbook of Small Animal Orthopedics and Fracture Repair.* 5th edn., Elsevier, Michigan, USA, pp. 33-56.

Gardhouse, S., & Sanchez, A. (2022). Rabbit sedation and anesthesia. *Veterinary Clinics of North America: Exotic Animal Practice, 25*(1)*,* 81-210.

Helmer, P.J., & Lightfoot, T.L. (2002). Small exotic mammal orthopedics. *Veterinary Clinics of North America: Exotic Animal Practice, 5*(1)*,* 169-182.

Jeon, S., Jang, J., Lee, G., Park, S., Lee, S.K., Kim, H., & Choi, J. (2020). Assessment of neovascularization during bone healing using contrast-enhanced ultrasonography in a canine tibial osteotomy model: a preliminary study. *Journal of Veterinary Science, 21*(1)*,* 1-10.

Kamran, K., Rashid, I., Mohd, Z., & Tengku, A.I. (2009). Repair of compact bone critical sized defect with natural originated scaffold in rabbit. *Journal of Animal and Veterinary Advance, 8*(8)*,* 1616-1623.

Kaur, A., Kumar, A., Kumar, D., Mohindroo, J., & Saini, N.S. (2015). Feasibility of C-arm guided closed intramedullary pinning for the stabilization of canine long bone fractures. *Veterinary World, 8*(12)*,* 1410-1415.

Langley-Hobbs, S., & Harcourt-Brown, N. (2013). *Fracture management.* BSAVA, United Kingdom, pp. 283-304.

Mammal, S., & Kapatkin, A.S. (2020). *Fundamentals of Fracture Repair.* 3rd edn., WB Saunders, Philadelphia, p.483.

Miwa, Y., & Carrasco, D.C. (2019). Exotic mammal orthopedics. *Veterinary Clinics of North America: Exotic Animal Practice, 22*(2)*,* 175-210.

Oezak, A., Yardimci, C., Ho, N., & Ys, Ş. (2009). Treatment of long bone fractures with acrylic external fixation in dogs and cats:

Retrospective study in 30 cases (2006 2008). *Journal of the Faculty of Veterinary Medicine Kafkas University, 15*(4), *615-622*.

Pead, M.J., & Carmichael, S. (1989). Treatment of a severely comminuted fracture in a rabbit using a Kirschner-Ehmer apparatus. *Journal of Small Animal Practice, 30*(10), 579-582.

Peirone, B., Rovesti, G.L., Baroncelli, A.B., & Piras, L. (2012). Minimally invasive plate osteosynthesis fracture reduction techniques in small animals. *Veterinary Clinics of North America: Small Animal Practice, 42*(5), 873-895.

Piermattei, D.L., & Flo, G.L. (1997). Fractures: Classification, diagnosis and treatment. In: *Handbook of Small Animal Orthopedics and Fracture Repair.* 5th edn., Elsevier, USA, pp. 124-146

Rich, G. A. (2002). Rabbit orthopedic surgery. *Veterinary Clinics of North America: Exotic Animal Practice, 5*(1), 157-168.

Sasai, H., Fujita, D., Seto, E., Denda, Y., Imai, Y., Okamoto, K., Okamura, K., Furuya, M., Tani, H., & Sasai, K. (2018). Outcome of limb fracture repair in rabbits: 139 cases (2007-2015). *Journal of the American Veterinary Medical Association, 252*(4), 457-463.

Snedecor, G.W., & Cochran, W.G. (1994). *Statistical Methods*. 8th edn., Affiliated East-West Press Pvt. Ltd., New Delhi, India, pp. 53-58.

Tunio, A., Jalila, A., Meng, G.Y., & Shameha, I. (2014). Experimental fracture healing with external skeletal fixation in a pigeon ulna model. *Journal of Advanced Veterinary and Animal Research, 1*(2), 58-64.

Von der Ahe, C., Marahrens, H., Schwarze, M., Angrisani, N., & Reifenrath, J. (2023). Pressure sensing mat as an objective and sensitive tool for the evaluation of lameness in rabbits. *Public Library of Science One, 18*(7), p.e0286918.

White, D.T., Bronson, D.G., & Welch, R.D. (2003). A mechanical comparison of veterinary linear external fixation systems. *Veterinary Surgery, 32*(6), 507-514.