RESEARCH ARTICLE Indian Journal of Animal Research, Volume 60 Issue 3: 493-500 (March 2026)

Evaluation of Figure-of-eight Cerclage Wire Technique for Distal Femoral Physis Fractures (Salter-Harris Type I and Type II) in Cats

Kerem Yener[1], Ali Hayat[1], Ünal Yavuz[1], Kübra Dikmen İlginoğlu[1], Mehmet Salih Karadağ[1], Mehmet Sıdık Hurma[1]

10.18805/IJAR.BF-1980

ABSTRACT

Background: This study aimed to present information regarding the technique and results regarding the figure-of-eight cerclage wire application in the treatment of salter-harris type I and II fractures of the distal femoral physis in cats. This study included 30 cats with femoral fractures in one extremity.

Methods: The evaluated data included animal characteristics (species, age and sex), fracture characteristics (etiology, duration, salter-harris classification, preoperative and postoperative displacement), surgical information (cerclage wire diameter and duration of surgery) and outcome assessment information (functional results, radiographic results and complications). Bone healing was observed between 6-8 weeks on postoperative radiographic evaluation in all cases. Long-term outcome assessments revealed complete functional results in most animals (96.6%, n=28). The overall complication rate was 26.6% (n=8) and all complications were classified as minor. Radiographs of the affected and contralateral extremities indicated shortening in 27 cats, but this finding was not statistically significant, either clinically or radiographically, considering the functional results. Preoperative fracture displacement was 3rd degree in most patients (70%, n=21), in which figure-of-eight cerclage wire techniques were assessed.

Result: Postoperative evaluation revealed 85% anatomical reduction or minimal malreduction. In conclusion, this study demonstrated that figure-of-eight cerclage wire application could be preferred as an alternative technique for the treatment of salter-harris type I and II fractures of the distal femoral physis in cats.

Key words: Cats, Cerclage wires, Femur, Salter-harris fractures.

INTRODUCTION

Distal femoral fractures account for 20-32% of femoral fractures in cats and commonly involve the physis in immature animals, particularly between 4 and 11 months of age (Gill *et al.*, 2018; Bondonny *et al.*, 2023; McNicholas *et al.*, 2002). Salter-Harris type I and II fractures are most prevalent, representing around 77% of cases (Çağatay *et al.*, 2013; Rubinos *et al.*, 2021; Altuğ *et al.*, 2019). Surgical intervention is typically required to ensure anatomical reduction and protect future growth (Voss *et al.*, 2007), with emphasis on preserving vascular supply and avoiding implant-related compression (Altunatmaz *et al.*, 2017; Dhanalakshmi *et al.*, 2020; Guiot *et al.*, 2017; Roberts *et al.*, 2022). Given the distal femoral physis's major contribution to limb growth 75% of femoral and 40% of overall limb length physeal-sparing techniques are essential, especially since closure may be delayed in neutered males (Bondonny *et al.*, 2023; Perry *et al.*, 2014).

Various osteosynthesis techniques have been employed for distal femoral physeal fractures in cats, including normograde or retrograde intramedullary pinning, open or fluoroscopy-assisted percutaneous pinning and Rush or cross-pinning methods (Cebeci *et al.*, 2021; Gill *et al.*, 2018; Altuğ *et al.*, 2019; Boekhout-Ta *et al.*, 2017; Pravalika *et al.*, 2023). While these approaches have yielded successful outcomes, limitations such as insufficient rotational or distraction stability, unsuitability for chronic fractures and a heightened risk of premature physeal closure particularly with cross-pinning have been reported (Boekhout-Ta *et al.*, 2017; Hudson *et al.*, 2020; Voss *et al.*, 2009; Bondonny *et al.*, 2023). Recent studies suggest that parallel K-wire placement may better preserve longitudinal growth and reduce physeal stress compared to cross-pinning (Inal *et al.*, 2019; Ma *et al.*, 2017). This highlights the potential advantages of techniques that minimize physeal

[1]Department of Surgery, Faculty of Veterinary Medicine, Harran University, Şanlıurfa/Turkey.

Corresponding Author: Kerem Yener, Department of Surgery, Faculty of Veterinary Medicine, Harran University, Şanlıurfa/Turkey. Email: keremyener@harran.edu.tr

ORCIDs: https://orcid.org/0000-0002-6947-0356, https://orcid.org/0000-0002-8597-0705, https://orcid.org/0000-0002-4981-2355, https://orcid.org/0000-0002-6805-1571, https://orcid.org/0000-0002-4139-913X, https://orcid.org/0000-0001-7804-6752.

How to cite this article: Yener, K., Hayat, A., Yavuz, U., İlginoğlu, K.D., Karadağ, M.S. and Hurma, M.S. (2026). Evaluation of Figure-of-eight Cerclage Wire Technique for Distal Femoral Physis Fractures (Salter-Harris Type I and Type II) in Cats. *Indian Journal of Animal Research*. **60(3):** 493-500. doi: 10.18805/IJAR.BF-1980.

Submitted: 18-02-2025 **Accepted:** 04-05-2025 **Online:** 14-06-2025

contact. Among them, the figure-of-eight cerclage wire, placed parallel to the distal and proximal fragments, requires further investigation. Initially, clinical outcomes were first reported by Spångberg *et al.* (2019), with this study aiming to evaluate its efficacy in a larger cohort, assessing short-, medium- and long-term outcomes in treating Salter-Harris type I and II distal femoral fractures in cats.

MATERIALS AND METHODS

Study group

This study included 30 cats with Salter-Harris type I or II distal femoral fractures, treated with a figure-of-eight cerclage wire at Harran University Veterinary Faculty (2020-2023). Only cases with complete radiographs and regular postoperative follow-ups were included. Clinical evaluations included vital signs (temperature, pulse, respiratory rate; Mindray UMEC12VET), hemogram (pocH-100i®, Sysmex), serum biochemistry (Spotchem EZ SP 4430, Arkray) and blood gas analyses (GEM Premier Plus 3000). Parameters such as WBC, RBC, MCV, MCH, MCHC, hemoglobin, glucose, creatinine, cholesterol, ALT, AST, bilirubin, albumin and CRP were assessed. Bone palpation, crepitation, soft tissue damage and neurological exams were conducted to monitor recovery and prevent complications. Data collected included breed, sex, age, fracture type (open/closed), cerclage wire diameter, complications and follow-up outcomes (short-, mid- and long-term). The study protocol was approved by the Local Ethics Committee on Animal Experiments, Harran University (session and permit number: 2023-008/07).

Surgical procedure

Anesthesia was induced with propofol (3 mg/kg, IV) following premedication with xylazine HCl (0.1 ml/kg, IM). Sevoflurane (2-3%) and 100% oxygen maintained anesthesia throughout the procedure. The surgical site was disinfected with benzalkonium chloride and povidone-iodine and intraoperative fluid therapy (NaCl 0.9%, 10 ml/kg/h) was provided. The cats were positioned in lateral recumbency, with the affected leg on top. The distal femur was exposed *via* arthrotomy, using a lateral or medial parapatellar approach and the patella was displaced to access the fracture site (Hudson *et al.*, 2004) (Fig 1A). A unilateral approach was employed, following the method described by Spångberg *et al.* (2019). After cleaning the fracture fragments and ensuring a clear operative field, cranial traction was applied to the proximal tibia for reduction. Two parallel holes were drilled into the fracture fragments using a 1 mm Kirschner wire. Cerclage wires (1.25-1.5 mm diameter, 10 cm length) (Fig 1B) were threaded through these holes and alternately tightened from both the lateral and medial sides to stabilize the fracture (Fig 1C). The distal and proximal holes were positioned to optimize fixation and prevent caudal displacement of the distal fragment. The wires were placed in a figure-of-eight configuration, ensuring the intersection point was slightly proximal to the fracture site to avoid patellar interference. After tightening the wires with a cerclage wire tool (Greatlh Betterhealh®, China), the excess wire was trimmed, leaving approximately three folds on each side (Fig 1D). The patella was repositioned and the joint was irrigated with saline. Crystalline penicillin (Vetimycin, Vetas, Turkey) was administered to reduce infection risk and the joint capsule was closed with absorbable Polyglycolic Acid sutures (Alcasorb, Katsan, Turkey). The surgical field was closed in layers, with no intraoperative complications observed. Postoperative radiographs confirmed fracture stability. The cats were recommended six weeks of cage rest, with Robert Jones bandaging for two weeks. Meloxicam (0.03 mg/kg, SC) was given for 3 days and amoxicillin-clavulanic acid (12.5 mg/kg, PO) was prescribed for 7 days (closed fractures) or 3-6 weeks (open fractures). Short-term physiotherapy started after bandage removal. Radiographs were taken every two weeks for 6-8 weeks to monitor healing.

Follow-up assessment

Postoperative assessments were carried out at 2 weeks, 6-8 weeks and at mid-term (6-12 months) and long-term

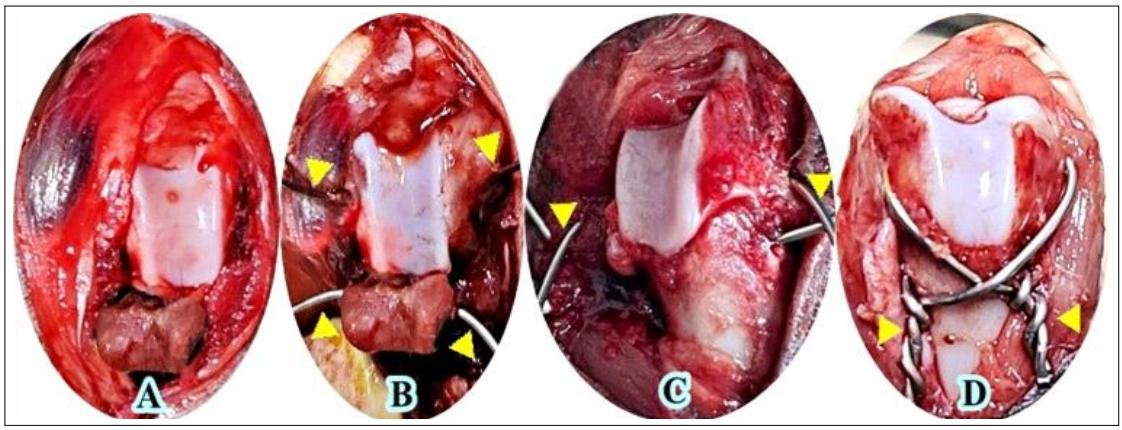


Fig 1: A) Proper opening of the operation site in a case of Salter-Harris type I. B) Placement of cerclage wires in distal and proximal fracture sites. C) Performing the fracture reduction and starting the figure-of-eight knot procedure. D) The final image of the operation site before closure following the creation of the figure-of-eight cerclage configuration.

(>1 year) through telephone interviews. Veterinarians and owners were asked about lameness or pain in the treated limb, with further care or diagnostics provided as needed.

Outcome evaluation involved grading lameness on a 5-point scale (0 = normal, 1 = mild limping with partial weight bearing, 2 = severe limping with partial weight bearing, 3 = severe limping with intermittent weight bearing and 4 = no weight bearing), a validated owner questionnaire and radiographic assessments of both the treated and healthy limbs (Cook *et al.*, 2010). Functional outcomes were categorized as complete, acceptable, or unacceptable, based on the return to pre-fracture status. Complications were classified as destructive, major, or minor, with destructive complications leading to permanent dysfunction or euthanasia, major requiring further intervention and minor resolving without additional treatment (Arkader *et al.*, 2007). All complications and treatments were documented.

Radiographic assessment

Orthogonal radiographs of the fractured femur were taken preoperatively, postoperatively and at follow-ups (2nd, 4th, 6th and 8th weeks). Three observers, including the surgeons, evaluated the radiographs. Preoperative fractures were classified according to the Salter-Harris system and categorized by displacement severity as described by Arkader *et al.* (2007). Degree 1= <1/3 of bone width; degree 2= 1/3 to 2/3 of bone width; degree 3= >2/3 of bone width. (Fig 2) postoperative radiographs confirmed correct placement of cerclage wires and satisfactory alignment. Wire positioning was considered satisfactory if placed correctly in the distal and proximal fragments, with the intersection point slightly proximal to the fracture site, arranged in a figure-of-eight to prevent interference with patellar function. Cortical alignment was also assessed, with slight overreduction in the mediolateral view deemed acceptable. Bone healing was evaluated using a scoring system from Cook *et al.* (2010), based on the presence of a step between the metaphysis and physis at the fracture site. Fracture reduction was classified as. Grade 0= Anatomical reduction, grade 1= Minimal malreduction (<1 mm), grade 2= Moderate malreduction (1-3 mm), grade 3= Severe malreduction (>3 mm). Bone healing was assessed based on bone bridging or the disappearance of radiolucent areas in the fracture line, with healing judged as satisfactory or unsatisfactory by the surgeons. The growth plate was monitored for closure at each follow-up, with partially closed plates considered closed. Complications related to bone healing were recorded. Orthogonal radiographs from both the affected and contralateral limbs were used to measure bone length differences. Measurements were made with standardized positioning and a 10 cm calibration mark for accuracy (Boekhout-Ta *et al.*, 2017).

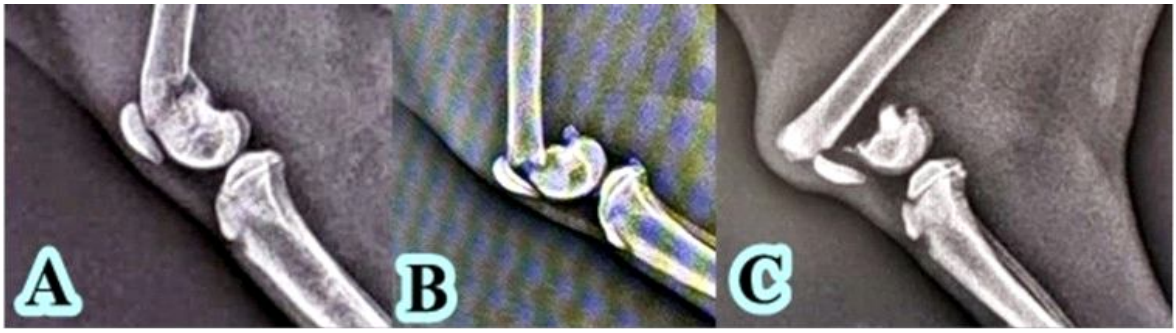
Statistical analysis

Statistical analyses were performed using SPSS 22.1. Mean and standard deviation were calculated for continuous variables (*e.g.*, age, clinical and laboratory results) and frequency and percentage values for categorical variables (*e.g.*, fracture type and sex). The chi-square test assessed the relationship between fracture type and complications. The Independent T-Test was used to examine the relationship between fracture type and severity of postoperative lameness. One-way ANOVA evaluated postoperative radiographic findings and fracture healing. Pearson Correlation Analysis assessed the relationship between postoperative complications and recovery time. The Intraclass Correlation Coefficient (ICC) determined the agreement between the surgeons' radiographic evaluations. Statistical significance was set at $p<0.05$.

RESULTS AND DISCUSSION

Study group

This study included 30 cats (30 femurs) with salter-harris type I (56.7%, 17/30) or type II (43.3%, 13/30) femur fractures. No cases of open reduction or fixation were excluded. The hematological, biochemical and blood gas values of all cats, including those with open fractures, were within the reference ranges (Table 1). The sex distribution was: neutered male (MC) 20% (6/30), neutered female (FN) 23.3% (7/30), non-neutered male (M) 40% (12/30) and non-neutered female (F) 16.7% (5/30). Breeds included domestic



A) 1st degree displacement (<1/3 bone width), B) 2nd degree displacement (1/3-2/3 bone width) and C) 3rd degree displacement (>2/3 bone width).

Fig 2: Radiographs of 3 cats.

short-haired (DSH) 33.3% (10/30), Scottish Fold 16.7% (5/30), British Shorthair 16.7% (5/30), Van Cat 13.3% (4/30), Siamese 16.7% (5/30) and Angora 3.3% (1/30). The mean age at surgery was 8.1±2.2 months (range 4-11 months), with a mean weight of 4.5±0.5 kg. Most fractures (73.3% [22/30]) were caused by falls from height, while the cause remained unknown in 26.7% (8/30). The average perioperative fracture duration was 2.4±1.3 days. Two open fractures were noted in 6.7% (2/30): Case 23 (British shorthair, 11 months, salter-harris type II) and case 27 (scottish fold, 10 months, salter-harris type II).

Preoperative radiographic assessment

Inter-surgeon agreement in the preoperative radiographic assessment was high (ICC=0.89 (89%), p=0.002). In the preoperative fracture displacement evaluation, degree 3:70.0% (21/30) of these cases were cats falling from a height. In other cats, Degree 2:20.0% (6/30) were Degree 1:10.0% (3/30).

Surgical findings

In this study, two 10 cm long cerclage wires (1.25 mm in 70% [21/30] and 1.5 mm in 30% [9/30]) were safely used in all cases. Intraoperatively, except in cases with fracture displacement degree 1, the holes in both the proximal and distal fragments were pre-drilled before starting the fracture reduction. This method was considered more practical in cases with degrees 2 and 3. The average operative time was 37±5 minutes, excluding anesthesia time. No intraoperative complications were observed.

Postoperative radiographic and outcome evaluation

The total follow-up period averaged 16.8±5.1 months, ranging from 10 to 26 months. All 30 cats were evaluated clinically and radiographically. Inter-surgeon agreement on radiographic evaluation was high (ICC = 0.91, 91%, p = 0.011). Bone healing was observed in 83.3% (25/30) of cases by 6 weeks postoperatively and in 16.7% (5/30) by 8 weeks (Fig 3 A-G, Fig 4 A-F). Growth plates were visible in 16.7% (5/30) of the femurs, with open growth plates noted in all patients younger than five months preoperatively. Postoperative fracture displacement was classified as degree 0 in 13 cases, degree 1 in 10 cases, degree 2 in 5 cases and degree 3 in 2 cases. No significant difference in bone healing was found with respect to fracture type (p = 0.11). Anatomical or minimal malreduction occurred in 85% of cases (Fig 5 A-D).

Lameness, assessed after removal of the Robert Jones bandage in the second postoperative week, showed a mean score of 0.11±0.07 for type I fractures and 0.21±0.03 for type II fractures, with no significant difference (p = 0.43). Shortening of the affected bones was observed in 90% (27/30) of neutered male and female cats (Fig 6 A-D). Bone

Table 1: Clinical and laboratory findings of cats.

Parameter	Mean ± SD	Reference values
Body temperature (°C)	38.5±0.5	(38.0-39.0)
Pulse rate (bpm)	150.0±15.0	(120-180)
Respiration rate (breaths/minute)	30.0±5.0	(20-40)
WBC (10^3/µL)	12.5±2.0	(5.5-19.5)
Lymphocytes (10^3/µL)	4.5±1.0	(1.5-7.0)
Monocytes (10^3/µL)	0.7±0.2	(0.1-1.4)
RBC (10^6/µL)	7.2±0.8	(5.0-10.0)
MCV (fL)	45.0±5.0	(39.0-55.0)
Haematocrit (%)	35.0±3.0	(30.0-45.0)
MCH (pg)	15.5±1.5	(13.0-17.0)
MCHC (g/dL)	34.0±1.5	(30.0-36.0)
Hemoglobin (g/dL)	11.5±1.0	(9.0-15.0)
Glucose (mg/dL)	100.0±15.0	(70-150)
Creatinine (mg/dL)	1.2±0.2	(0.9-1.9)
Cholesterol (mg/dL)	150.0±20.0	(75-220)
ALT (U/L)	45.0±10.0	(12-130)
AST (U/L)	35.0±8.0	(15-66)
Total bilirubin (mg/dL)	0.5±0.1	(0.1-0.6)
Albumin (g/dL)	3.5±0.5	(2.6-3.9)
CRP (mg/L)	5.0±1.0	(<10.0)
pH	7.4±0.05	(7.35-7.45)
pCO2 (mmHg)	40.0±5.0	(32-48)
pO2 (mmHg)	95.0±10.0	(80-110)

Abbreviations: Mean: mean; SD: Standard deviaton; WBC: White blood cell; RBC: Red blood cell; MCV: Mean corpuscular volume; MCH: Mean corpuscular hemoglobin; MCHC: Mean corpuscular hemoglobin concentration; ALT: Alanine aminotransferase; AST: Aspartate transaminase; CRP: C-reactive protein.

elongation occurred in only 10% (3/30), but this was not clinically or radiographically significant (p = 0.068).

In terms of complications, 73.3% (22/30) of cases had no complications. Mild edema was observed in 23.3% (7/30), resolving with two weeks of rest. One case (3.3%, 1/30) experienced mild infection, which resolved with local povidone iodine treatment. No significant correlation was found between fracture type and postoperative complications (p = 0.15), but a significant positive correlation was found between postoperative complications and recovery time (r = 0.62, p = 0.022).

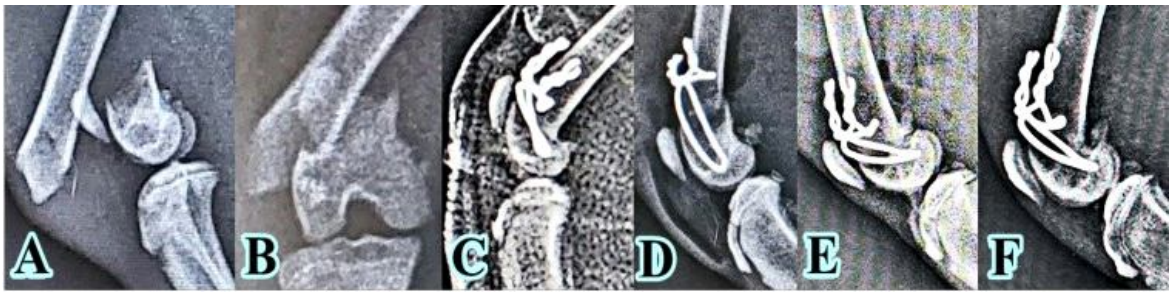
Owner and veterinarian satisfaction was high, with all participants reporting full functional recovery. Mid-term follow-up (6-12 months) showed a full function rate of 83.3% (25/30), with mild limping in 16.7% (5/30). Long-term follow-up (>1 year) revealed that 96.6% (28/29) had full function, with only one case (3.4%, 1/29) showing acceptable intermittent limping. Case 6, which was adoptedby another owner, was excluded from the long-term evaluation but was reported to have no complications.

Salter-Harris type I and II fractures in cats are critical due to their involvement with growth plates, affecting bone



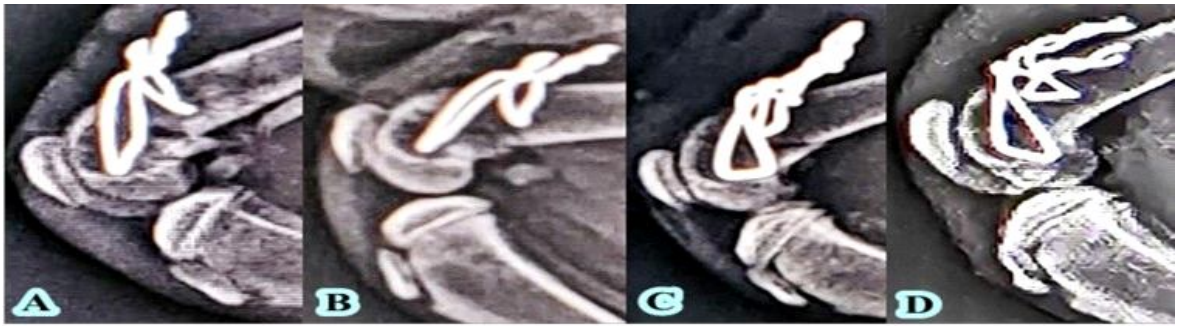
A-B) Preoperative radiograph. C) Postoperative day 0 radiograph. D-E) Postoperative 2nd week radiographs F) Postoperative 4th week radiographic image. G) Postoperative 6th week (complete healing) radiographic image.

Fig 3: Radiographic images of a patient with distal femoral salter-harris type I fracture (Case 3).



A-B) Preoperative radiographs. C) Postoperative day 0 radiograph. D) Postoperative 2nd week radiograph. E) Postoperative 4th week radiograph. F) Postoperative 6th week radiograph (complete healing).

Fig 4: Radiographic images of a case with distal femoral salter-harris type II fracture (Case 12).



A-B) 6th and 8th week radiographs for case 23 (Type II). C-D) 6th and 8th week radiographic images for case 24 (Type II).

Fig 5: Radiographic images of the genu joint in flexion in cases treated with the figure-of-eight cerclage wire technique.

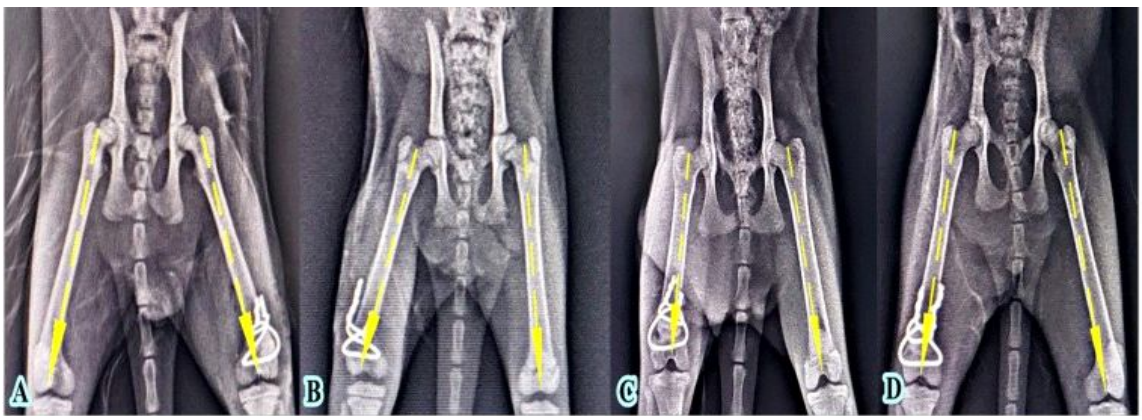
development (Rubinos *et al.*, 2021; Bondonny *et al.*, 2023). While traditional methods like cross-pinning and intramedullary fixation are common (Çağatay *et al.*, 2013; Boekhout-Ta *et al.*, 2017), the figure-of-eight cerclage wire technique offers a practical, minimally invasive alternative. This study shows a 96.6% functional recovery rate, comparable to or exceeding conventional methods (Cebeci *et al.*, 2021; Spångberg *et al.*, 2019; Bondonny *et al.*, 2023). The technique's simplicity, shorter operative time and stability against shear forces make it particularly advantageous for cases involving muscular traction and chronic fractures. These results align with prior research emphasizing the biomechanical benefits of tension band principles in managing physeal fractures (Spångberg *et al.*, 2019; Altuğ *et al.*, 2019), supporting its viability as a primary treatment option for Salter-Harris I/II fractures in feline patients.

Femoral physeal fractures in cats predominantly involve salter-harris types I and II, with a male predisposition (73.3% in this cohort) linked to behavioral traits that increase trauma risk (Çağatay *et al.*, 2013; Gill *et al.*, 2018; Haq *et al.*, 2024). Falls from heights are the primary cause (Brioschi *et al.*, 2016), which aligns with this study's population treated using the figure-of-eight cerclage wire. This technique showed similar efficacy for both salter-harris I and II fractures, with comparable healing times (median: 6.2 weeks) and complication rates (23.3%), supporting its biomechanical suitability for uniplanar fractures under shear forces (Rubinos *et al.*, 2021). The prevalence of salter-harris I/II fractures likely results from physeal vulnerability to bending stresses rather than gender-specific biological factors.

Conventional techniques for Salter-Harris I/II femoral fractures in cats, such as cross-pinning and intramedullary fixation, offer favorable outcomes (93% success) but come with risks like pin migration, articular damage and joint pathology if not placed correctly (Çağatay *et al.*, 2013; Bondonny *et al.*, 2023). While cross-pinning is biomechanically robust against rotation, it requires precise placement to avoid complications (McNicholas *et al.*, 2002). Intramedullary fixation, though less invasive, lacks rotational stability and can damage cartilage in comminuted fractures (Cebeci *et al.*, 2021). In contrast, the figure-of-eight cerclage wire technique, utilized in this study, offers superior adaptability, using tension band principles to counter muscular forces and allowing gradual reduction, especially beneficial for chronic cases. This technique optimizes compression and stability (Spångberg *et al.*, 2019) and smaller-diameter wires (1.25-1.5 mm) proved effective in younger cats (6-11 months), suggesting age- and weight-based customization improves safety). Unlike pinning methods, cerclage wires minimize cartilage trauma and procedural complexity, while achieving high functional recovery rates (96.6%), positioning the technique as a reliable alternative where traditional methods may be limited.

Postoperative bandaging, though common, can cause skin lesions and morbidity, especially with prolonged use (Miraldo *et al.*, 2020). This study advocates for a shorter 2-week immobilization period, which aligns with Cebeci *et al.* (2021), showing no adverse effects. Extended bandaging (>3 weeks) can worsen conditions like coccyfemoral luxation (Altuğ *et al.*, 2019). The 2-week protocol effectively balanced fracture stabilization and soft-tissue protection, highlighting the importance of monitoring bandage duration based on fracture stability and patient needs (Miraldo *et al.*, 2020; Valk *et al.*, 2020).

Traditional methods like cross-pinning and intramedullary fixation for salter-harris fractures carry risks such as pin migration, infection and osteoarthritis (Çağatay *et al.*, 2013; Bondonny *et al.*, 2023). In contrast, the figure-of-eight cerclage wire technique in this study showed onlyminor complications lameness (23.3%) and mild infection (3.3%) which resolved with conservative management. Abaxial wire placement effectively prevented patellar irritation, enhancing safety. These findings support the technique's reliability and lower morbidity compared to conventional approaches, consistent with previous research (Spångberg *et al.*, 2019; Cebeci *et al.*, 2021).



Radiographs of cases A) Case 3 (Type I), B) Case 6 (Type I), C) Case 12 (Type II) and D) Case 27 (Type II).

Fig 6: In the 8th-week postoperative radiograph, limb improvement was observed with the figure-of-eight cerclage wire, although some shortening compared to the contralateral limb was noted. Despite this, excellent function was reported by the cat owners.

Early growth plate closure and limb shortening are common after physeal fractures, but their clinical impact in cats is minimal. In this study, early closure occurred in 90% of cases without affecting long-term function, consistent with previous findings (Spångberg *et al.*, 2019; Rubinos *et al.*, 2021). Younger cats (<5 months) showed delayed closure, supporting age-related physeal resilience (Bondonny *et al.*, 2023). Despite frequent limb shortening, mobility remained excellent, suggesting that early closure does not compromise functional outcomes. Further research is needed on age-specific physeal healing.

Preoperative fracture displacement significantly influences treatment strategies in physeal fractures. This study found that 70% of cases required open reduction due to severe displacement, aligning with previous veterinary and human studies (Gill *et al.*, 2018; Boekhout-Ta *et al.*, 2017). The figure-of-eight cerclage wire technique provided anatomical or near-anatomical alignment in most cases (76.7%), demonstrating its effectiveness in complex fractures. Compared to fluoroscopy-assisted methods, it offered a practical alternative with shorter anesthesia time (Boekhout-Ta *et al.*, 2017), supported by high inter-surgeon agreement in postoperative evaluations.

Although long-term follow-up of physeal fracture management is limited in veterinary literature, the figure-of-eight cerclage technique in this study demonstrated excellent short-term radiographic healing (6-8 weeks) and a 96.6% rate of long-term functional recovery. These outcomes are comparable to those reported for cross-pinning and intramedullary fixation methods (Bondonny *et al.*, 2023; Spångberg *et al.*, 2019). Mild lameness observed in 16.7% of cases at intermediate follow-up largely resolved by the long term, with only 3.4% showing intermittent limping. The larger cohort and extended follow-up enhance the reliability of these findings, although telephone-based assessments may introduce bias. Overall, the results underscore the efficacy of the cerclage wire technique and the need for standardized, objective protocols for long-term functional evaluation.

CONCLUSION

To conclude, the figure-of-eight cerclage technique may be used as an alternative treatment modality to conventional applications in Salter-Harris type I and II fractures of the distal femoral physis commonly encountered in cats. Findings based on a larger number of cases (30 cats), preoperative and postoperative radiographic evaluations and long-term functional results confirmed the safety of this technique.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the Harran University of Animal Care Committee. (session and permit number: 2023-008/07).

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Altuğ, M.E., Yurtal, Z., Yılmaz Devecı, M.Z., İşler, C.T. and Alakuş, H. (2019). Treatment of coxofemoral luxation and type-1 salter harris femur fracture in a cat by toggle pin and cross pin methods. *Van Veterinary Journal.* **30(1):** 67-69.

Altunatmaz, K., Karabağlı, M., Aydın, D., Güzel, Ö., Yalın, E.E., Uğurlu, Ü., Şadak, D.J. and Ekici, H. (2017). The treatment of supra-condylar and diaphyseal femoral fractures in cats using intramedullary two-way stacked Kirschner wire application. *Turkish Journal of Veterinary and Animal Sciences.* **41(2):** 19. doi: 10.3906/vet-1606-12.

Arkader, A., Warner, W.C., Horn, B.D., Shaw, R.N. and Wells, N. (2007). Predicting the outcome of physeal fractures of the distal femur. *Journal of Pediatric Orthopaedics*. **27:** 703-708. doi: 10.1097/BPO.0b013e3180dca0e5.

Au, K., Mattern, K.L. and Lewis, D.D. (2008). Dicondylar humeral fracture stabilization in a dog using a transilial rod and external fixation. *Journal of Small Animal Practice.* **49(3):** 148-151. doi:10.1111/j.1748-5827.2007.00399.x.

Boekhout-Ta, C.L., Kim, S.E., Cross, A.R., Evans, R. and Pozzi, A. (2017). Closed reduction and fluoroscopic-assisted percutaneous pinning of 42 physeal fractures in 37 dogs and 4 cats. *Veterinary Surgery.* **46:** 103-110. doi: 10.1111/vsu.12582.

Bondonny, L., Jacqmin, M., Ferrand, F.X., Taroni, M. and Rivier, P. (2023). Use of a modified intramedullary pinning technique for distal femoral physeal salter-harris type I and II fracture management: A retrospective study of 31 cats. *Veterinary and Comparative Orthopaedics and Traumatology*. doi: 10.1055/s-0043-1776332.

Brioschi, V., Langley-Hobbs, S.J., Kerwin, S., Meeson, R. and Radke, H. (2016). Combined physeal fractures of the distal radius and ulna: Complications associated with K-wire fixation and long-term prognosis in six cats. *Journal of Feline Medicine and Surgery.* pp. 1-8. doi: 10.1177/1098612X16653644.

Cebeci, M.T. and Karslı, B. (2021). Treatment of cats' distal diaphyseal and supracondylar femur fractures with dynamic intram-edullary cross pinning technique. *Harran Üniversitesi Veteriner Fakültesi Dergisi.* **10(2):** 184-190. doi: 10.31196/huvfd.1008198.

Cinti, F., Pisani, G., Vezzoni, L., Peirone, B. and Vezzoni, A. (2017). Kirschner wire fixation of salter-harris type IV fracture of the lateral aspect of the humeral condyle in growing dogs: A retrospective study of 35 fractures. *Veterinary and Comparative Orthopaedics and Traumatology*. **30:** 62-68. doi: 10.3415/VCOT-16-05-0071.

Cook, J.L., Evans, R., Conzemius, M.G., Lascelles D.X., *et al.* (2010). Proposed definitions and criteria for reporting time frame, outcome and complications for clinical orthopedic studiesin veterinary medicine. *Veterinary Surgery.* **39:** 905-908. doi: 10.1111/j.1532-950X.2010. 00763.x.

Çağatay, S. and Sağlam, M. (2013). Kedi ve köpeklerde karşılaşılan salter-harris kırıklarının sağaltim sonuçlarının klinik ve radyolojik değerlendirilmesi. *Ankara Üniversitesi Veteriner Fakültesi Dergisi.* **60:** 109-116.

Dhanalakshmi, S., Nath, I., Das, M.R., Panda, S.K., Kundu, A.K., Mishra, U.K. and Parvathamma, P.S. (2020). Epidemiological and clinical studies in cats with thoracolumbar vertebral fracture and luxation and ıts management. *Indian Journal of Animal Research*. **55(5):** 553-560. doi: 10.18805/ijar.B-3984.

Gill, K.K., Kumar, A., Sangwan, V., Anand, A., Mahajan, S.K. and Mohindroo, J. (2018). Comparative functional outcome of supracondylar femoral fracture stabilized with cross and end-threaded intramedullary pinning in dogs. *Indian Journal of Animal Sciences*. **88(2):** 161-169. doi: 10.56093/ijans. v88i279313.

Guiot, L.P. and Déjardin, L.M. (2017). Fracture of the femur. In veterinary surgery: Small Animal, Elsevier Health Sciences. **2:** 1019-1071.

Haq, A.U., Malik, H.U., Randhawa, S.S., El-Shazly, M. and Chandran, D. (2024). Behavioural disorders in dogs and cats: A review. *Agricultural Reviews*. **45(3):** 514-519. doi: 10.18805/ag.R-2410.

Hudson, C.C., Kim, S.E. and Pozzi, A. (2020). Percutaneous pinning for fracture repair in dogs and cats. *Veterinary clinics: Small Animal Practice*. **50(1):** 101-121. doi: 10.5167/uzh-178470.

Hudson, J.T., Slater, M.R., Taylor, L., Scott, M.H. and Kerwin, S.C. (2004). Assessing repeatability and validity of a visual analogue scale questionnaire for use in assessing pain and lameness in dogs. *American Journal of Veterinary Research.* **65:** 1634-1643. doi: 10.2460/ajvr.2004.65. 1634.

Inal, S., Gok, K., Gok, A., Pinar, A.M. and Inal, C. (2019). Comparison of biomechanical effects of different configurations of kirschner wires on the epiphyseal plate and stability in a salter-harris type 2 distal femoral fracture model. *Journal of the American Podiatric Medical Association.* **109(1):** 13-21. doi: 10.7547/16-112.

Ma, J., Wang, T., Lovric, V., Johnson, K.A. and Walsh, W.R. (2017). A biomechanical comparison of kirschner-wire fixation on fracture stability in salter-harris type I fractures of the proximal humeral physis in a porcine cadaveric model. *BMC Veterinary Research.* **13:** 306. doi: 10.1186/s12917-017-1225-y.

McNicholas, W.T. Jr., Wilkens, B.E., Blevins, W.E., Snyder, P.W., McCabe, G.P., Applewhite, A.A., Laverty, P.H. and Breur, G.J. (2002). Spontaneous femoral capital physeal fractures in adult cats: 26 cases (1996-2001). *Journal of the American Veterinary Medical Association.* **221(12):** 1731-1736. doi: 10.2460/javma.2002.221.1731.

Miraldo, D., Salmelin, B. and Yeadon, R. (2020). Feline distal tibial physeal fracture repair using a modified cross-pin technique with four pins. *Veterinary and Comparative Orthopaedics and Traumatology.* **33:** 220-226. doi: 10.10 55/s-0039-1701007.

Pavarotti, G.S. and Boudrieau, R.J. (2018). Treatment of a pediatric distal femoral malunion deformity. *Veterinary and Comparative Orthopaedics and Traumatology.* **31(3):** 222-228. doi:10. 1055/s-0038-1637754.

Perry, K.L., Fordham, A. and Arthurs, G.I. (2014). Effect of neutering and breed on femoral and tibial physeal closure times in male and female domestic cats. *Journal of Feline Medicine and Surgery.* **16:** 149-156. doi: 10.11771098612X13502977.

Pravalika, E., Reddy, M.J.K., Latha, C., Rao Madhava, T. and Purshotham, G. (2023). A clinical study on the use of supracondylar plate in the treatment of distal femoral fractures in dogs. *Indian Journal of Animal Research.* **57(9):** 1168-1176. doi: 10.18805/IJAR.B-4742.

Roberts, V.J. and Meeson, R.L. (2022). Feline femoral fracture fixation: What are the options? *Journal of Feline Medicine and Surgery.* **24(5):** 442-463. doi: 10.1177/1098612X221090391.

Rubinos, C. and Journal, R.L. (2021). Traumatic physeal fractures in cats: A review of 36 cases (2010-2020). *Journal of Feline Medicine and Surgery*. pp. 1-9. doi: 10.1177/1098612X 211005886.

Spångberg, C., Spångberg, I.B. and Bergström, A. (2019). Stainless steel wire in a figure-of-eight for repair of distal femoral physeal fractures in ten cats: A case report. *Journal of Veterinary Science.* **20(6):** e71. doi: 10.4142/jvs.2019.20.e71.

Valk, N. and Schumacher, J. (2020). Successful outcome of a standardbred filly after conservative treatment for a salter-harris type III fracture of the distal femoral condyle. *Equine Veterinary Education.* **32(4):** 178-181. doi: 10.111 1/eve.12935.

Voss, K., Langley-Hobbs, S. and Montavon, P.M. (2009). Femur. In Feline Orthopaedic Surgery and Musculoskeletal Disease. *Saunders Elsevie*. pp. 455-474.

Voss, K. and Lieskovsky, J. (2007). Trauma-induced growth abnormalities of the distal radius in three cats. *Journal of Feline Medicine and Surgery.* **9(2):** 117-123. doi: 10.1016/ j.jfms.2006.09.002.

Yoo, S., Kim, D.H., Lee, Y., Yeo, S. and Kim, H.Y. (2019). Spontaneous femoral capital physeal fracture with proximal tibial epiphyseal dysplasia in a cat. *Journal of Veterinary Clinical Studies.* **36(2):** 112-115. doi: 10.17555/jvc.2019.04.36.2.112.