Article published online: 2023-10-31

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

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Vet Comp Orthop Traumatol 2024;37:107–114.

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Abstract

Objective To report a modified intramedullary pinning technique, and associated outcomes, for distal femoral physeal Salter–Harris type I and II fracture management in cats.

Study Design Retrospective study including client-owned cats presented between November 2014 and February 2022 with distal femoral physeal fractures treated with an intramedullary pin and one antirotational pin inserted in the lateral femoral condyle. Collected data included signalment, fracture characteristics according to the Salter–Harris classification, surgical data (intramedullary and antirotational pin sizes), and outcome data (radiographic and functional outcomes and complications).

Results Thirty-one cats were included in this study. Bone healing was radiographically confirmed 6 to 8 weeks postoperatively in all cases. The majority of cats (30/31) were classified as full functional outcomes at mid-term follow-up. The overall mid-term complication rate was 3% (1/31). Implant migration was not observed and implant removal was not needed in any case.

Conclusion The modified intramedullary pinning technique for distal femoral Salter–Harris I and II fracture management in cats was associated with an full functional outcome.

Keywords
- fracture
- fixation
- femur
- Salter–Harris
- physeal fracture

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Introduction

Growth plate fractures are commonly reported following trauma in immature cats with open physes. This type of fracture is most commonly described in cats aged 6.5 to 10 months.[1–3] Radiographic classification of these fractures into five configurations was developed by Salter and Harris.[4] Surgical treatment is generally indicated for these fractures and has several objectives. The first is to restore correct alignment of the bone. In addition, although the physis may close due to the initial trauma regardless of the implant used, surgeons attempt to repair such fractures to maintain normal bone growth after complete healing.[5,6] The second objective is to preserve vascularization as much as possible, which requires a particular choice of implant, as well as minimal dissection of the tissues. These considerations are even more important in cases of trauma affecting the distal femoral physis, which is responsible for 75% of the growth in length of this bone.[7] The distal femoral growth plate remains open until the age of 12.4 to 17.5 months in cats[8] and closure can occur even later in neutered male cats.[9] Concerning the choice of implants in cases of distal femoral physeal fractures, it appears that the use of smooth pins is less likely to disturb growth.[10]

Various methods of distal physeal femoral fracture osteosynthesis have been described, including a single intramedullary pin placed in a normograde or retrograde fashion, two or more intramedullary pins, intramedullary

received
October 13, 2022
accepted after revision
September 27, 2023
article published online
October 31, 2023

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Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

DOI https://doi.org/10.1055/s-0043-1776332.
ISSN 0932-0814.

pin augmented with an antirotational pin, Rush pin, and cross pin.[11–16] In addition, cross pin or Rush pin osteosynthesis can be performed via an open approach or using minimally invasive technique like fluoroscopic-assisted percutaneous pinning.[17,18] Satisfactory results have been reported with all of these techniques but intramedullary pinning does not theoretically provide rotational or distraction stability. Moreover, a minimally invasive approach for the Rush or cross pin technique cannot be performed in chronic fractures.[17–19] With an open approach, cross or Rush pinning requires both a lateral parapatellar and a small medial approach to the stifle joint achievable through a single skin incision made lateral to the articulation.[19,20] Therefore, we assumed that surgical repair of distal physeal femoral fractures in cats using an intramedullary pin inserted normograde from the distal epiphysis and augmented with a laterally applied antirotational Kirschner wire would provide adequate stability to achieve satisfactory bone healing with limited risk for complications. This technique was first described by Parker in 1984 in a case series of 11 dogs and cats.[15,16] Here, we report the mid- and long-term outcomes after using this technique to manage Salter–Harris type I and II fractures of the distal femur in cats.

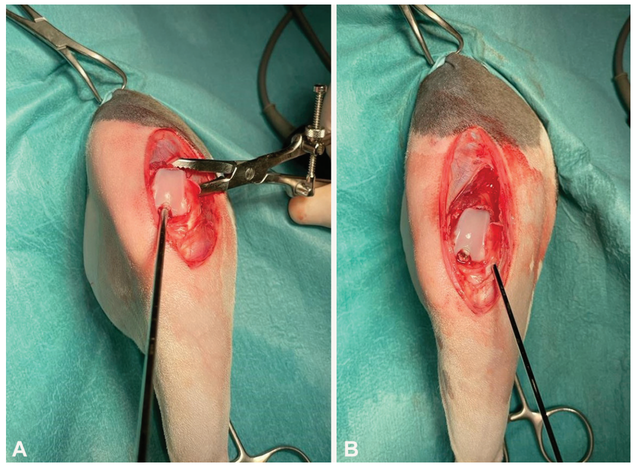

Fig. 1 Intraoperative images. Intramedullary pin was inserted via the intercondylar fossa, immediately cranial to the site of insertion of the caudal cruciate ligament (**A**). Insertion point of the antirotatory pin was immediately caudal and distal to the tendon of origin of the long digital extensor muscle, at a 30- to 45-degree angle with respect to the long axis of the femur (**B**).

Materials and Methods

Study Population

We reviewed medical records of client-owned cats presented with Salter–Harris type I or II distal physeal femoral fracture that underwent stabilization between November 2014 and February 2022 at CHV OnlyVet with an intramedullary implant and one antirotational pin inserted laterally. Cats were included if they had complete radiographic follow-up and clinical records for at least 6 months post-surgery.

Collected data included signalment, fracture description, fracture management, pre- and postoperative radiographs, complications, radiographs 6 to 8 weeks postoperatively, and clinical outcome. All surgical interventions were performed by a board-certified surgeon.

Surgical Procedure

A lateral parapatellar approach and arthrotomy was performed[21]; the patella and quadriceps femoral muscle were reflected medially to inspect the fracture site and the articulation. When needed, this approach was extended proximally on the distal shaft of the femur. Fracture reduction was achieved by applying cranial traction to the proximal tibia, with the stifle held in flexion and the talocrural joint in extension. With the fracture held in slight overreduction by stifle extension, a Steinmann pin was inserted into the medullary cavity via the intercondylar fossa, immediately cranial to the site of insertion of the caudal cruciate ligament, in a retrograde, distal-to-proximal direction until it was firmly inserted into the proximal femoral cortical bone (►**Fig. 1A**). The pin was then retracted distally by 3 mm and the distal end of the intramedullary implant was cut 3 mm from the articular surface and re-advanced flush with the bone surface. A second antirotational implant, either a Kirschner wire or a Steinmann pin, was inserted laterally. The insertion point was located immediately caudal and distal to the tendon of origin of the long digital extensor muscle, at a 30 to 45-degree angle with respect to the long axis of the femur in the sagittal plane (►**Fig. 1B**). Proximally, this pin was advanced through the transcortex and the distal tip of the pin was either bent and cut off or cut off to the bone. The patella was returned to its anatomical position. The joint capsule was sutured using interrupted pattern with absorbable monofilament suture (Monosyn, B. Braun Vetcare S. A. Rubi, Spain). The surgical site was closed routinely.

Cats were discharged the same day or the day after the surgery. Immediate postoperative care included cage rest for 6 weeks, nonsteroidal anti-inflammatory (meloxicam, 0.05 mg/kg, *per os*, once a day, for 5 days), analgesic (tramadol, 3–5 mg/kg, *per os*, thrice a day, for 3 days) therapy, as well as antibiotics in open fracture cases (amoxicillin and clavulanic acid, 12.5 mg/kg, *per os*, twice a day, for 3–6 weeks).

Follow-Up Assessment

Cats were re-examined 2 weeks and again 6 to 8 weeks after surgery. Mid-term (from 6 months to 1 year) and long-term (over 1 year) follow-up was carried out by phone interview. The referring veterinarian and the owner were contacted and asked if the cat had presented any episode of lameness or pain on the injured limb and if so, whether this motivated a consultation with the veterinarian and required additional diagnostic tests or further treatment.

During all follow-up examinations, a clinical outcome assessment was performed as described previously.[22] Functional outcome was classified as full, acceptable, or unacceptable and complications were classified as catastrophic (causing permanent unacceptable function), major (requiring additional treatment), or minor (not requiring additional surgical or medical treatment to resolve).[22]

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Fig. 2 Postoperative radiographs of a distal femoral Salter–Harris type I fracture: caudocranial (A) and mediolateral (B) projections.

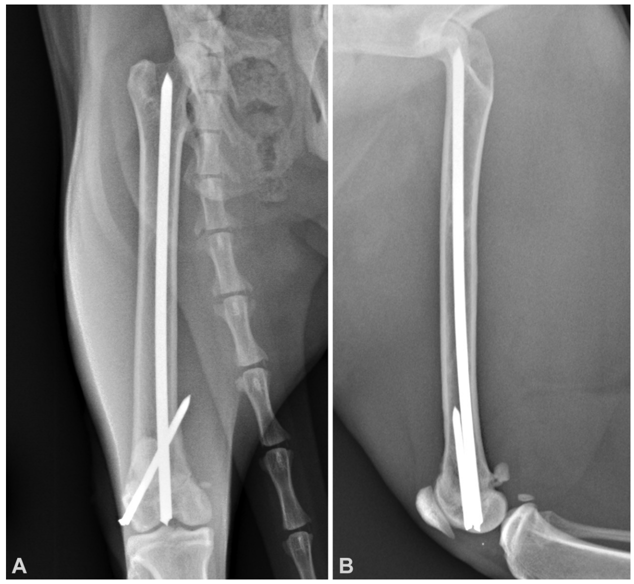

Fig. 3 Follow-up radiographs 6 weeks post-surgery of a distal femoral Salter–Harris type I fracture: caudocranial (A) and mediolateral (B) projections.

Radiographic Assessment

Orthogonal radiographs of the affected femur were obtained pre- and postoperatively and at follow-up, 6 to 8 weeks post-surgery. Radiographs were reviewed by three observers including a board-certified surgeon. Fractures were classified according to the Salter–Harris classification using preoperative radiographs. Postoperative radiographs were used to validate accurate implant placement, as well as satisfactory alignment of the fractured ends (►**Fig. 2**). The positioning of the implants was considered satisfactory if the intramedullary implant was correctly implanted in the medullary cavity and through the proximal cortex. The antirotational implant had to purchase enough bone distally and cross the intramedullary implant proximal to the fracture line. Alignment was considered satisfactory if the cortices were aligned on the mediolateral and caudocranial views. A slight over-reduction of the fracture, visualized on the mediolateral view, was tolerated. Bone healing was assessed at radiographic follow-up (►**Fig. 3**). Radiographic signs consistent with bone healing were bone bridging seen on mediolateral and caudocranial radiographic projections or loss of radiolucency of the fracture site. Each of those items was judged on the radiographs to be satisfactory or not by consensus of the three observers. In addition, for each follow-up radiograph, the growth plate was assessed and it was noted whether it was open or closed. Partially closed growth plates were noted as closed. Complications of bone healing were noted.

Results

Demographics

A total of 31 cats (33 femurs) met the inclusion criteria for this study (►**Table 1**), including 28 domestic shorthair, one Maine coon, one Persian, and one British shorthair cat. There were 9 spayed females, 3 intact females, 12 castrated males, and 7 intact males. The mean age at the time of surgery was 9.1 months (3–16 months). Ten cats were 5 months old or younger. Fractures were Salter–Harris type I in 20 cases and type II in 13 cases. Four fractures were classified as open and all of these were open type I.

Surgical Findings

The intramedullary implants used in this study were Steinmann pins with a diameter of 2.5 mm in 20 femurs, 2 mm in 9 femurs, and 1.8 mm in 3 femurs. Radiographically, these implants occupied 47.4% (29.8–57.1%) of the medullary cavity on average. The antirotational implants were smooth Kirschner wires or Steinmann pins depending on the cat's size, with a diameter between 1.25 and 2 mm. The diameter of this second implant was 2 mm in 2 femurs, 1.8 mm in 10 femurs, 1.6 mm in 12 femurs, 1.4 mm in 8 femurs, and 1.25 mm in 1 femur. No intraoperative complications were reported.

Outcome Assessment

On radiographic examination 6 to 8 weeks postoperatively, bone healing was present in all cases. The growth plates appear as open in 9/33 femurs. For the cases presented before the age of 5 months, it appeared open in 6/10 femurs. Short-term complications were noted in five fracture cases. Two were minor complications, with the development of a seroma on the lateral aspect of the stifle joint, while major complications were present in three fracture cases. In one cat, persistent lameness was noted 6 weeks postoperatively. On radiographs, osteomyelitis was suspected. The lameness resolved after a 6-week course of antibiotics (amoxicillin and clavulanic acid, 12.5 mg/kg, *per os*, twice a day). The two other major complications were grade IV patellar luxation, lateral in one case and medial in the other. These cats were respectively 4 and

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Table 1 Patient population

Number	Breed	Sex	Age (mo)	Lateralization	Fracture description	Implant size			Open fracture	Short-term complication	Duration of follow-up (in months)	Outcome	
						IM implant	% of medullary canal occupied by IM implant	Antirotational pin				Mid-term (6–12 months)	Long term (>1 year)
1	DSH	F	5	R	I	2	40.8	1.4	O	Persistent lameness: suspected osteomyelitis	25	Full	Full
2	Maine Coon	FN	13	R	I	2.5	43.2	1.8			24	Full	Full
3	DSH	MC	10	L	II	2.5	51.9	1.8			12	Full	Full
4	DSH	M	9	L	I	2.5	50.9	1.4		Seroma	10	Full	Full
5	DSH	MC	14	R	I	2.5	43.8	1.4			8	Full	–
6	DSH	MC	13	L	I	2.5	56.2	1.8			7	Full	–
7	DSH	MC	12	L	II	2.5	49.6	1.8			6	Full	–
8	DSH	F	4	R	II	1.8	29.8	1.25		Grade IV medial patellar luxation	7	Unacceptable (medial patellar luxation grade IV)	–
9	DSH	MC	11	R	I	2.5	45.1	1.8			6	Full	–
10	DSH	FN	5	R	II	2	50.3	1.4	O	Seroma	6	Full	–
11	DSH	MC	12	R	II	2.5	48.9	1.8			30	Full	Full
12	DSH	M	3	L	I	1.8	47.4	1.4		Grade IV lateral patellar luxation: revision surgery	9	Full	–
13	DSH	MC	13	R	II	2.5	45.5	1.8			22	Full	–
14	DSH	M	4	L	I	2	43.7	1.4			8	Full	–
15	DSH	MC	12	L	I	2.5	46.1	1.6			9	Full	–
16	DSH	MC	13	R	I	2.5	48.3	2			40	Full	Full
17	Persan	MC	15	L	I	2.5	47.2	1.6			62	Full	Acceptable (intermittent lameness)
18	DSH	FN	9	R	II	2	41.1	1.6			55	Full	Full
19			10	R	I	2.5	50.1	1.6			33	Full	Full

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Table 1 (*Continued*)

Number	Breed	Sex	Age (mo)	Lateralization	Fracture description	Implant size			Open fracture	Short-term complication	Duration of follow-up (in months)	Outcome	
						IM implant	% of medullary canal occupied by IM implant	Antirotational pin				Mid-term (6–12 months)	Long term (>1 year)
20	DSH	FN	10	L	I	2.5	49.2	1.6			33	Full	Full
21	DSH	M	5	L	I	2	57.1	1.6			36	Full	Full
22	DSH	FN	9	L	II	2.5	46.9	1.6			6	Full	–
23	DSH	M	5	L	II	2	50.1	1.6			24	Full	Full
24				R	II	2	52.1	1.6			24	Full	Full
25	DSH	F	3	L	I	1.8	40.4	1.4			36	Full	Full
26	DSH	M	7	L	I	2.5	48.6	1.6	O		8	Full	–
27	British Shorthair	FN	7	L	I	2.5	51.1	1.6			12	Full	Full
28	DSH	FN	8	R	II	2.5	42.6	1.6			60	Full	Full
29	DSH	M	6	R	I	2	55.2	2			53	Full	Full
30	DSH	MC	16	R	I	2.5	46.3	1.4			6	Full	–
31	DSH	MC	16	L	II	2.5	51.1	1.8			6	Full	–
32	DSH	M	5	L	I	2	54.4	1.8	O		7	Full	–
33	DSH	FN	13	L	II	2.5	48.9	1.8			7	Full	–

Abbreviations: DSH, domestic shorthair; F, female; FN, neutered female; L, left; M, male; MC, castrated male; O, Open; R, right.

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3 months old at the time of the procedure. In the case of the lateral grade IV luxation, revision surgery showed exuberant bone production on the cranial aspect of the femur, in continuity with the former fracture site and with adhesions to the quadriceps muscle, deviating it laterally. Discrete instability of the construct or calcification of the fibrous callus initially present was suspected. The patellar luxation resolved after removal of these osseous proliferations with a bone rongeur. This cat presented no further complications. For the second cat, medial patellar luxation was radiographically associated with a varus of the distal femur and the anatomical lateral distal femoral angle of 116° absent on the postoperative radiograph. Revision surgery was declined by the owner.

A mid-to-long-term follow-up phone interview was performed after an average of 21 months (range: 6–62 months). Mid-term functional outcome was full for 32 (96.8%) cats, with no reported lameness or pain, and unacceptable in one (persistent lameness due to grade IV medial patellar luxation). Long-term outcome was available for 18 cats. Functional long-term outcome was full for 17 (94.4%) cats. For one cat, an intermittent lameness of the operated limb was noted 14 months after surgery. Radiographs were unremarkable. The lameness was self-limiting with 2 weeks of rest. No implant migration was reported in the long term.

Discussion

This study reports the use of a modified intramedullary pinning technique for distal femoral physeal Salter–Harris type I and II fracture management in cats. Bone healing was present at radiographic follow-up 6 to 8 weeks postoperatively and, in the longer term, owners reported a return to normal activity in the majority of cases.

Surgical management is challenging given the proximity of the joint and the need to use implants that allow the bone to continue to grow in length.[7] However, it is necessary for the implant to purchase enough bone, especially in the small epiphyseal fragment, in order to achieve stability of the construct.[7,15] Anchoring using an intramedullary pin, as described in this technique, helps with alignment. Indeed, when placed in a normograde fashion, in a distal-to-proximal direction, satisfactory reduction or even slight overreduction is necessary to obtain correct positioning of the implant within the medullary cavity.[7,15] Use of pin inserted through the intercondylar fossa causes minimal joint pathology if correctly embedded within the bone.[11,15] An intramedullary pin is not resistant to rotational or compressive forces[7] even in the femoral distal physis.[11,13,23] Furthermore, increasing the number of intramedullary implants does not increase stability and may be responsible for more articular cartilage damage.[24]

Biomechanically, the presence of two implants, inserted in a different orientation and achieving multiple point fixation in both the proximal and distal fragments, improves the strength of the construct.[13] Therefore, we used an antirotational pin, inserted into the lateral femoral condyle and penetrating the medial cortex of the distal femoral metaphysis, in a similar fashion to what is achieved with a cross-pinning technique. Good to excellent outcomes are reported in 92 to 93% of cases treated with cross-pinning and dynamic cross-pinning techniques,[12,17] which is comparable to the results obtained in our study. However, various studies report migration or loosening of the implant, requiring a second procedure for removal in 8 to 14% of cases.[2,12] In our study, no implant migration was reported postoperatively and implants were not removed. In addition, when an open approach is needed, cross-pinning and dynamic cross-pinning required soft tissue dissection on the lateral and medial aspects of the distal femur to place accurately the implants.[19,20] This type of situation is encountered when fluoroscopy is not available or when the patient is not a good candidate for a minimally invasive approach.[18]

A possible negative point of this technique is that it could cause articular cartilage damage if the intramedullary implant migrates distally. These situations were not encountered in this study. Moreover, it was chosen not to remove the implants unless necessary because articular cartilage may also be damaged if the implant requires surgical removal. Long-term follow-up could only be reported for an average of 21 months in this study. Thus, a later migration of the intramedullary implant remains possible but considered unlikely. Therefore, the presence of an implant left within bone for years may not be harmless and should be monitored in the long term. Another drawback of this technique is that it cannot be used in the management of fractures with comminution within the intercondylar region as this is the insertion point of the intramedullary implant. However, Salter–Harris type I and II fractures are the most frequently reported in cats.[2,11,25,26] Furthermore, the position of the entry point of this implant is, in our opinion, a key point of this technique and should be done carefully. Poor placement could result in caudal cruciate ligament injury if inserted too distally or conflict with the patella if inserted too proximally within the trochlea. In addition, implant should be flush with the bone surface to avoid the risk of interference with the patella and the development of cartilage damage as an implant protruding into the joint would be in the patellar tracking when the stifle is in flexion (►**Fig. 4**).

Finally, one of the major concerns in physeal fracture repair is the preservation of the growth plate and the progression of bone lengthening. In this study, there was subjectively no evidence of functional deficit secondary to growth arrest in any but one case in which a grade IV medial patellar luxation associated with a valgus of the femoral distal extremity was reported. The residual growth potential of the cats in this study, aged 9 months old on average, was limited, which may partly explain this result. At follow-up, the growth plate appeared radiographically closed in 72.3% of cases 6 to 8 weeks postoperatively. However, given the age of the cats, this may be normal closure or a consequence of the initial trauma or surgery. Among the 10 cases aged 5 months or less at the time of surgery, radiographic closure of the growth plate was noted in four cases (40%). Clinically, eight did not show any lameness during 6 months after surgery. In the last one, an angular deformity was present as early as 6 weeks postoperatively, causing medial patellar luxation. Possible explanations for this complication are a

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Fig. 4 Postoperative radiographs of a distal femoral Salter–Harris type I fracture: mediolateral projection of the stifle joint in flexion.

suboptimal fracture reduction during surgery or implant failure with a collapse of the lateral aspect of the fracture site. The use of a small, undersized antirotational implant in this case (1.25 mm) supports this explanation. However, a premature asymmetric closure of the growth plate cannot be excluded as a consequence of an injury of the growth plate.[27] To measure the safety of this method for growth plates, radiographic follow-up of the contralateral femur could evaluate a possible length deficit. While growth arrest is rare after osteosynthesis with a cross pin, the use of these implants may result in a low rate of physeal injury when pins are placed either centrally or peripherally in the physis.[10] We, therefore, assume that the risk of growth arrest with our technique is as low as with the cross-pinning technique.

The main limitations of this study are its retrospective nature and the small number of cases. Moreover, the follow-up of the cats after complete healing was only clinical. Radiographs were only performed by the referring veterinarians when lameness recurred. It was performed in one case presented for an intermittent lameness 14 months after surgery. Therefore, it is possible that we underestimated the number of long-term complications, such as implant migration or the development of osteoarthritis, if these were not associated with lameness.

This retrospective study of 33 fractures shows that osteosynthesis with an intramedullary Steinmann pin and a single antirotational smooth Kirschner wire or Steinmann pin inserted laterally gives full functional outcome in 96.9% of cases and represents an alternative to the techniques commonly used for the management of Salter–Harris type I and II fractures of the distal femoral physis in cats.

Authors' Contribution

L.B. contributed to study design, acquisition of data, and data analysis and interpretation. M.J., F.-X.F., and M.T. contributed to acquisition of data and data analysis and interpretation. P.R. contributes to conception of study, study design, acquisition of data, and data analysis and interpretation. All authors drafted, revised, and approved the submitted manuscript.

Conflict of Interest

None declared.

Acknowledgment

We thank Leah Cannon, PhD, for the English language editing of this manuscript.

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