Treatment Outcomes for Periprosthetic Femoral Fractures in Cementless Press-Fit Total Hip Replacement

Isobel C. Monotti[1] Christopher A. Preston[2] Scott W. Kidd[3]

[1] Small Animal Surgery Department, The Animal Hospital at Murdoch University, Perth, Australia
[2] Pet Emergency and Specialist Centre, Melbourne, Australia
[3] Sierra Veterinary Specialist and Emergency Centre, Reno, Nevada, United States

Address for correspondence Isobel C. Monotti, BVSc, MANZCVS, The Animal Hospital at Murdoch University, Nyarrie Drive, Murdoch, Western Australia 6150, Australia (e-mail: Isobel.monotti@murdoch.edu.au).

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Abstract

Objective The aim of this study was to report outcomes in dogs with periprosthetic femoral fractures associated with a press-fit cementless femoral total hip replacement implant.

Materials and Methods Electronic medical records and digital radiographs were used to identify dogs with periprosthetic femoral fractures associated with press-fit cementless total hip replacement. Data collected included signalment, weight, time of fracture, cause of fracture, presence of intra-operative fissure, fracture type, repair technique, and clinical and radiographic outcomes. Long-term patient outcome was assessed by communication with owners or referring veterinarians.

Results Twenty-eight dogs with femoral fracture repair associated with cementless press-fit total hip replacement were identified. Eight of the fractures occurred intraoperatively and 20 occurred at a median of 2 days postoperatively. An oblique or spiral configuration was noted in 19 cases and 15 occurred at the distal end of the femoral stem (type B), with thirteen type B1, one type B2 and one type B3 fractures. Fractures were repaired with non-locking (18/28) or locking-plate fixation (10/28). Cerclage wire was applied around the plate and proximal bone segment in 17/28 dogs. Major complications occurred in 7/28 cases (five deep infection, two mechanical failures). Bone healing was noted in 21/23 cases, for which follow-up radiographic interpretation was available. Return to function was complete in 17 cases, acceptable in 8 cases and unacceptable in 3 cases.

Conclusions While cementless total hip replacement periprosthetic femoral fractures can be successfully repaired with lateral plate fixation, the risk of infection appears to be high.

Keywords
- cerclage wire
- fracture healing
- implant infection
- arthroplasty
- periprosthetic femoral fracture

Introduction

Periprosthetic femoral fractures are a complex complication of total hip replacement (THR). These fractures are challenging to repair due to the scarcity of proximal bone stock available for fixation of both the femoral stem and purchase of implants such as bone screws. Femoral fracture is reported to occur in 2.9% of canine cemented THR and between 5.1 and 13% of uncemented THR.[1–6] Identified risk factors for periprosthetic femoral fractures include age, low canal flare index, osteopathy and fissuring during femoral broaching or stem insertion.[2,3,7] Intra-operative femoral fissures more frequently occur when the stem is placed with a varus angle exceeding 5 degrees and maximum canal fill in the coronal plane.[1,6]

In people, periprosthetic femoral fractures occur in 1 to 5% of cementless femoral components.[8,9] Fractures are most commonly categorized and repaired according to the Vancouver system, with decision making largely dependent on radiographic assessment of fracture location, prosthesis stability and bone stock.[7,10,11] According to this algorithm,

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open reduction and internal fixation or minimally invasive percutaneous osteosynthesis is recommended for type B1 and C fractures, where the femoral stem is stable.[7] Revision arthroplasty with insertion of a long femoral stem and a cortical bone graft in addition to open reduction and internal fixation is recommended for type B2 and B3 fractures with an unstable stem.[7,8] The Coventry treatment algorithm also considers signs of pre-existing implant instability ('unhappy hips') such as deteriorating pain, mobility and atraumatic fracture formation as additional indicators for implant revision.[8]

Biomechanical studies have compared various repair constructs using cerclage wire, bone screws, cables, struts, compression and locking lateral plates as well as double plating.[12] Fracture fixation using a lateral bone plate, proximal unicortical and distal bicortical screws as well as proximal cables or cerclage is the most stable construct for periprosthetic femoral fracture repair when the bone is healthy.[12–14] Placement of a plate with proximal unicortical screws alone provides inadequate stability.[15] However, the combination of cables or cerclage wires around the bone and plate improves torsional stability and may prevent proximal screw pull-out.[13,16]

Reports of clinical outcome of cementless periprosthetic femoral fracture repair in the veterinary literature are relatively scarce, with most work focusing on the incidence of and risk factors for such fractures. Successful treatment of periprosthetic femoral fractures has been reported in five of six dogs using a string-of-pearls (SOP) locking plate and fracture healing has been observed within 6 to 10 weeks of fracture repair with application of a dynamic compression plate (DCP) and/or cerclage wire for cemented periprosthetic femoral fractures.[2,4] The recent use of a cerclage cable-plate system has also been described for the successful stabilization of a periprosthetic femoral fracture in a dog with limited bone stock.[17]

The aims of this study were to describe treatment options and clinical outcomes of dogs with periprosthetic femoral fracture associated with cementless THR.

Materials and Methods

Electronic medical records and digital radiographs for dogs that developed an intra- or postoperative femoral fracture with a press-fit cementless THR (BioMedtrix Inc., Whippany, New Jersey, United States) between January 2006 and March 2019 were reviewed. Dogs were included if complete medical records were available and if recheck radiographs were performed at least 6 weeks after surgery. Dogs were excluded if the fracture was related to stem explantation. A periprosthetic fracture was defined as a displaced fracture of the femur that occurred during the total hip procedure or in the postoperative period. Non-displaced fissures repaired intraoperatively with cerclage wire alone were not included. Information collected included patient signalment, body weight, time of fracture occurrence, fracture location and conformation, presence of intra-operative fissure formation, fracture repair method as well as any intra- and postoperative complications.

Long-term outcome, at least 6 months following repair, was assessed by telephone interviews between the authors and the owner or via communication with the referring veterinarian. Clinical outcome was assigned using previously described criteria.[18]

Fracture Repair Procedure

All fracture repair procedures were performed by the same surgeon (CAP). Dogs were pre-medicated and anaesthetized using a standardized protocol which included pre- and postoperative opiate analgesia and postoperative non-steroidal anti-inflammatory medications. Regional anaesthesia was achieved with epidural injection of morphine (0.2 mg/kg) and bupivacaine 0.5% (0.1 mg/kg). Perioperative antibiotic medications (cephazolin, 22 mg/kg intravenous) were administered at induction and then every 90 minutes throughout the procedure.

In all cases, a double layer impervious surgical stockinette was sutured to the dermis following the skin incisions (Cardinal Health Inc., Dublin, Ohio, United States). For postoperative fractures, patients were placed in lateral recumbency and a routine lateral approach was made to the fracture site, with separation of the biceps femoris and vastus lateralis muscles.[19] The hip was not approached, if possible. For intra-operative fractures, the surgical approach was extended distally to the patella. The fracture site was assessed for communicating fissures and the femoral stem was assessed for stability before the fracture was reduced with bone holding forceps. Fractures were repaired using either a locking (SOP; Orthomed Pty Ltd, Mandurah, Western Australia or locking compression plate [LCP], VOI, Augustine, Florida, United States) or non-locking plate (DCP; VOI, Augustine, Florida, United States) placed in a neutralization conformation. When cerclage wires were used, they were either placed around the bone in a conventional manner across spiral or long oblique fractures or placed around the bone and plate where the wire engaged the plate through an empty screw hole. A twist configuration was used in all cerclage wires. The chosen plate was contoured over the lateral aspect of the greater trochanter of the femur to allow placement of at least two bicortical screws in the greater trochanter, angled slightly distomedially to maximize bone purchase. Care was taken to ensure the screws did not contact the shoulder of the stem. The plate extended distally to the supracondylar region and was secured with bicortical screws. The surgical site was liberally lavaged and the hip assessed for stability before routine closure was performed with imbrication of the fascia lata.

Animals were discharged with a 5-day course of oral cephalexin (22 mg/kg PO BID) and a non-steroidal anti-inflammatory medication. Postoperative care consisted of 6 weeks of cage confinement. Dogs were assessed at 2 weeks for suture removal and again at 6 weeks for re-check radiographs. Radiographs were assessed for implant stability and fracture healing.

Results

Demographics

A total of 347 THR were performed using a cementless press-fit stem during the study period. Thirty displaced periprosthetic femoral fractures were identified and 28 of these cases met the inclusion criteria for the study. Seventy-five intra-operative fissures (21.6%) were recorded in this population, with thirteen of these propagating to displaced fractures (17.3%) requiring revision surgery. Results are summarized in ►**Appendix Table A** (online only).

The population consisted of five Golden Retrievers, three Border Collies, three Labrador Retrievers, two Rough Collies, two Staffordshire Bull Terriers, two German Shepherds and one each of Rhodesian Ridgeback, Rottweiler, Airedale Terrier, Standard Poodle, Pug, Heeler, Beagle, Samoyed, Russian Terrier, English Setter and cross breed. The median age at the time of surgery was 6 years and 1 month (range, 5 months to 10 years). The median body weight was 26.0 kg (range, 9.1–58 kg). All dogs were implanted with a press-fit cementless stem (BFX, BioMedtrix Inc., Whippany, New Jersey, United States). Twenty collarless and eight collared femoral stems were implanted. Thirteen of the stems had a titanium mesh coating and the other 15 had a cobalt chrome beaded coating. Fourteen THR were performed on the left side. In four dogs, the fracture occurred during their second THR.

Twenty of the fractures occurred in the postoperative period with a median time of 2.5 days between surgery and fracture (range, 1–45 days). Two dogs had reported trauma (a fall) as an inciting cause of fracture 7 and 16 days after surgery and two sustained a fracture after over-activity (16 and 13 days postoperatively). Four dogs had a median varus stem malposition of 4.7 degrees (range, 2.9–6.4 degrees). Thirteen of the postoperative fracture cases had developed fissures at the time of THR, all of which were stabilized with a median of two cerclage wires at the time of surgery (range, 1–3 wires). One dog developed a fracture due to stem subsidence 3 days after surgery, without prior fissure identification.

Eight of the fractures occurred intra-operatively. Two were sustained during broaching, one during impaction of the stem, one during external rotation of the femur prior to transection of the ligament of the head of the femur, two during reduction of the hip and two of unknown cause.

Fracture Classification and Repair

A majority of the postoperative fractures occurred in the femoral diaphysis, adjacent to the stem tip (type B, 13/20). Two of these diaphyseal fractures also included displacement of the greater trochanter. The stabilization of the greater trochanter fractures was incorporated into the repair of the type B fracture, with a bone plate and cerclage wires and were not managed as independent fractures.

The stem was stable in eleven fractures (type B1) and unstable in two postoperative fractures (one type B2 and one type B3). Seven of 20 postoperative fractures occurred distal to the femoral stem (type C). A majority of the postoperative fractures had an oblique conformation (13/20). Spiral (3/20), transverse (2/20), comminuted (1/20) and one unknown configuration were also noted. All of the intraoperative fractures were located in the femoral diaphysis. Reported fracture configurations included spiral (3/8), comminuted (4/8) and one unspecified configuration.

A standard lateral approach was made to the femur for repair of postoperative fractures and the joint was not disturbed. Stem stability was assessed via the fracture and unstable stems were retracted to allow reduction in the fracture before replacement of the stem and further stabilization with application of the bone plate. A median of three screws was placed in the greater trochanter (range, 2–4) and a median of two cerclage wires (range, 1–2) was placed around the proximal femur and plate at the time of primary repair in 17/28 dogs. Additional cerclage wires were placed around the bone and mid-section of the plate. A median of six (range, 3–10) distal, bicortical screws were placed. Thirteen of the postoperative fractures were repaired with a non-locking plate construct and seven with an SOP locking plate. Five of the intraoperative fractures were stabilized with a non-locking plate and three with a locking plate construct (2 SOP, 1 LCP) (►**Fig. 1**).

Radiographic Assessment

Radiographic evaluation revealed good fracture apposition and alignment following surgical repair. Radiographs, taken at a median of 67 days (range, 41–1633 days) after repair, were available for interpretation in 23/27 dogs that survived to follow-up. Radiographic fracture union was evident in 21/23 of these cases, with good progression to fracture healing with callus formation evident in one dog (case 11) and non-union reported in one case (case 20).

Complications and Postoperative Outcome

Seven dogs had a major complication associated with femoral fracture. Loss of proximal screw fixation occurred in two cases (cases, 20 and 24) (►**Fig. 2**). For case 24, proximal screw pull-out was initially managed with re-placement of longer, trochanteric screws and two cerclage wires over the proximal plate and bone. Plate breakage occurred 57 days post-revision and was repaired with a non-locking plate and four proximal cerclage wires around the plate and bone. The dog was ambulating well; however, the dog was euthanatized due to an oesophageal stricture before osseous union was confirmed. Explantation of the plate and cerclage wire was performed 30 months after repair in case 20 due to chronic lameness and pain attributed to proximal screw pull-out. Amputation was performed 1 month later due to stem instability and fracture non-union.

Five dogs (17.9%) developed deep/implant infections. One dog was managed with amputation, two had the plate and cerclage wires explanted, one was euthanatized and one was managed with a long course of oral amoxycillin-clavulanate when explantation was declined. The removed implants cultured positive for *Enterobacter aerogenes* (case 27) and a coagulase-negative *Staphylococcus* (case 20). One dog (case 10) had the implant removed 2 years following repair to manage a draining sinus and suspected deep infection; however, culture results of the implants were negative.

Subsidence occurred in four cases with retained BFX stems after fracture repair with a median subsidence of 5.75 mm (range, 2.0–9.0 mm) All of the dogs with post-repair subsidence had non-collared stems. One case of subsidence was noted secondary to suspected infection (case 10). Case

Fig. 1 Examples of a locking (string of pearls) construct (**A**) and a non-locking (dynamic compression plate) construct (**B**) for repair of periprosthetic femoral fractures with the addition of cerclage wires around the proximal plate and bone.

14 was revised with a cemented stem (Biomedrix Inc. Whippany, New Jersey, United States) after 9.0 mm subsidence resulted in ventral luxation. Subsidence had no clinical effect in the other two cases. Two dogs developed a superficial infection (minor complication). Telephone interviews with owners or referring veterinarians were available for all 28 cases with a median follow-up time of 1,298 days (range, 74–3992 days). One case was lost to long-term follow-up due to re-homing. Full function was achieved in seventeen dogs, an acceptable function regained in eight dogs and an unacceptable outcome was reported in three dogs.

Discussion

This study demonstrates that acceptable long-term clinical outcomes and complete bone healing can be achieved with press-fit cementless periprosthetic femoral fractures treated with a lateral bone plate and proximal cerclage wires. The findings of this study are consistent with previous veterinary reports.[2,4,17]

The incidence of femoral fracture (8.6%) is similar to previous reports for cementless THR in dogs[1,3] All fractures occurred within 6 weeks of surgery, before the expected time of osseointegration and is consistent with previous reports for cementless periprosthetic femoral fractures.[3,20,21] Femoral fracture was not a long-term complication in this study; however, it has been reported to occur up to 2,196 days postoperatively for cemented prostheses, indicating that effective osteointegration should protect against this complication.[2]

A non-locking, plate was used in the majority of cases (18/28) with a median of three screws placed in the greater

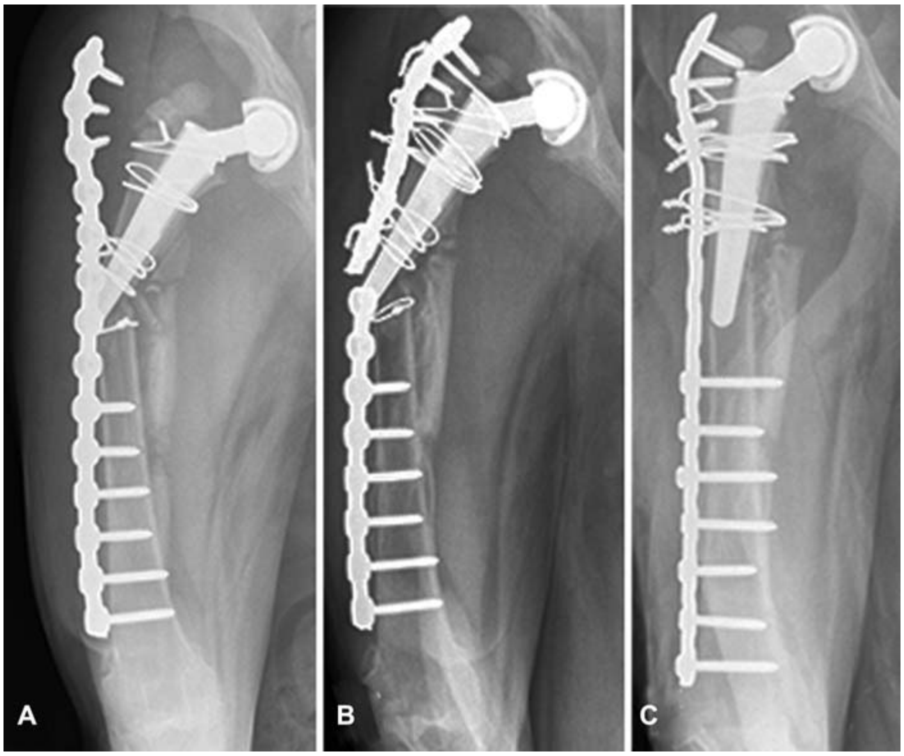

Fig. 2 Implant failure via proximal screw pull-out without the addition of cerclage wires around a string of pearls plate (**A**), cyclic plate failure (**B**) with preservation of the proximal screws and cerclage wires. Final revision included the placement of a non-locking dynamic compression plate and cerclage wires (**C**).

trochanter, proximal to the stem. The placement of these screws in the greater trochanter is integral to the stability and success of the fracture repair. Biomechanical evaluation of periprosthetic fracture repair in human models has shown that lateral plating with proximal unicortical screws had the best stability in axial compression; bending and torsion until failure by proximal screw pull-out.[13] This has not been assessed in canine models.

No difference was noted in clinical outcome or fracture healing between non-locking or locking constructs in this study. The potential benefits of SOP for repair of periprosthetic fractures have been described and largely relate to angular stability, increased screw pull-out strength and improved periosteal blood supply.[4] The benefit of using a non-locking system for the treatment of these fractures is the ability to direct bone screws in an orientation to maximize bone purchase in the presence of the femoral stem, particularly in the greater trochanter. The use of non-locking plates has been successfully described in 17 dogs with cemented THR, without complication.[2] In people, higher implant failure and non-union rates are reported for locking plate repairs of type B1 fractures, when compared with compression plating techniques. This may be due to alteration in strain at the fracture site and reduced fracture compression.[22]

The length of the femoral plate is an important aspect of repair. In people, application of a bone plate that extends from the greater trochanter to the femoral condyles around a stable stem is recommended and is associated with lower instances of implant failure and non-union compared with shorter-plate repairs.[22] This was achieved in all repairs in this series.

The only case of catastrophic implant failure (SOP plate) was attributed to cyclic fatigue. Proximal screw pull-out occurred in two cases, one with an SOP plate and one with non-locking plate. The application of secondary stabilizers in the form of cerclage wire or cables placed around the proximal aspect of the plate and greater trochanter and secured through the plate holes has been proposed to prevent screw pull-out and was successful in preventing recurrence of this complication in the case that had revision surgery.[4,13]

In people, multifilament cables are generally used instead of cerclage wires as cables have greater interfragmentary compression and frictional resistance than orthopaedic wire and are also less likely to crush osteoporotic trochanteric bone.[14,23] Biomechanical in vitro studies have shown that the addition of a cable cerclage doubles the stability of unicortical screw and plate constructs.[14] The biomechanical benefits of secondary stabilization with the use of a cable-plate construct following screw pull-out have been reported in one dog.[17]

Prevention of periprosthetic femoral fractures is largely achieved by avoiding reported risk factors, taking care to prevent fissures forming during femoral preparation and stem impaction and placing the stem in a neutral orientation.[6,24] The decision to implant a cementless THR stem in this study was based on patient selection and was not applied universally to all cases. The use of cemented THR stems should be considered in cases at risk of fracture to mitigate the incidence of this complication.

During reaming or broaching, the medial calcar region is watched closely for fissure formation; however, the depth of preparation in the femur is not necessarily monitored as closely. Tensile hoop strains of 125% are generated in the proximal femur during impaction of the press-fit stem and elevated tension may remain in the proximal femur if large stems are impacted when the isthmus has been under-reamed.[25] Similarly, the creation of unrecognized, longitudinal fractures in the femoral cortex of dogs has been demonstrated when the medulla is prepared with a rasp 0.5 mm smaller than the inserted stem, leading to fracture formation within 1 week after surgery.[26] The median time to fracture after THR in this study was 2 days and many of these fractures may have propagated from undetected fissures caused by under-preparation of the canal.

Sixty-five per cent (13/20) of postoperative fractures had a fissure detected during primary surgery and 13/75 fissures progressed to fracture. Previous reports of femoral fracture occurring despite cerclage stabilization of intra-operative fissures range from 0 to 45%.[1–3] Fissure stabilization with double-loop cerclage has been shown to restore stem stability and increase resistance to subsidence.[27] Stabilization with multiple cerclage wires placed at least 1 cm distal to the fissure has been recommended to protect against fracture propagation and the use of one to two cerclage wires in this study may not have addressed the most distal extent of the fissures in some cases.[2,27] In vivo studies have also shown reduced bone ingrowth at 6 weeks around cerclaged fissures that could contribute to implant micromotion and fracture propagation and cases with intraoperative fissure formation should be closely monitored for signs of implant instability in the early postoperative period.[28]

Eleven postoperative fractures were treated as type B1 fractures; however, undetected stem instability may have been present at the time of repair with subsidence noted post-fracture repair in four cases with retained non-augmented BFX stems. Assessing stem stability at the time of fracture repair can be challenging, as implant loosening may not be clearly apparent on radiographs nor easily determined by manipulation of the stem through the fracture gap.[8] In people, type B1 fractures have a 13% incidence of non-union and implant failure due to undetected stem instability and as a result, some surgeons have recommended treating femoral stems as unstable until proven otherwise.[29] Suspicion of stem instability should be high in cases where fracture has occurred beyond the time of expected osteointegration or with minimal trauma.

Major postoperative complications related to the periprosthetic femoral fractures occurred in 7/28 dogs. This is similar to previous reports of periprosthetic femoral fracture repair in dogs.[4] Deep/implant infections occurred in 5/28 dogs. Three deep infections developed after a second or third surgery, increasing the risk of subsequent infection.[30,31] Although this infection rate is higher than those reported for index THR, deep surgical site infection rates between 4.4 and 25% are reported in people treated for periprosthetic femoral fractures.[32–35] Possible explanations for the high infection rate could be due to the development of resistance to prophylactically administered cephalexin, extensive soft tissue dissection, prolonged surgical time, fracture associated trauma to surrounding tissues or the presence of pre-existing implants.[30,35] Femoral fracture revision was performed without entering the hip and with a stitched-in impervious stockinettes to minimize prosthesis infection. Collection of exit cultures for revision procedures may be beneficial in these higher risk cases.

Explantation with retention of the prosthesis was successful in two dogs with deep infection but failed to resolve chronic lameness in one dog with proximal screw pull-out, stem instability and fracture non-union. Fracture non-union is reported in 3 to 9% of people with periprosthetic femoral fractures and 73% are successfully managed with a single revision procedure using orthogonal bone plating, cancellous bone graft placement and stem retention.[36] Radiographs should be carefully evaluated for evidence of stem instability before explantation and stem revision or amputation considered in these challenging cases.

Limitations of this study are largely related to its retrospective nature and mild variations in fracture repair techniques between cases. It is not possible to make direct comparisons between plate suitability for the treatment of periprosthetic femoral fractures or to formulate specific guidelines for the treatment of these fractures, only to report the outcomes of the dogs in this series.

Periprosthetic femoral fractures can be a devastating complication of cementless THR. The findings of this study show that an excellent or good clinical outcome with bone union can be achieved in a majority of cases that are stabilized with a lateral plate with proximal screws placed in the greater trochanter and secondary cerclage wires.

Authors' Contributions

Isobel C. Monotti and Christopher A. Preston contributed to conception of study, study design, acquisition of data and data analysis and interpretation. Scott W. Kidd contributed to acquisition of data and data analysis and interpretation. All authors drafted, revised and approved the submitted manuscript.

Conflict of Interest

None declared.

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