Received: 15 September 2020 | Revised: 18 August 2021 | Accepted: 24 September 2021

DOI: 10.1111/vsu.13740

ORIGINAL ARTICLE - CLINICAL

WILEY

Outcome of canine cementless collared stem total hip replacement with proximal femoral periprosthetic cerclage application: 184 consecutive cases

Sarah K. Israel DVM, DACVS[1] | William D. Liska DVM, DACVS[2]

[1]BluePearl Stone Oak, San Antonio, Texas, USA

[2]Global Veterinary Specialists PLLC, Houston, Texas, USA

Correspondence
Sarah K. Israel, BluePearl Stone Oak, 503 E. Sonterra Blvd, San Antonio, TX 78258, USA.
Email: sarah.israel@bluepearlvet.com

Abstract

Objective: To report outcomes of cementless collared stem total hip replacement (THR) with proximal femoral periprosthetic cerclage application in dogs.

Study design: Retrospective case series.

Animals: Client-owned dogs ($n = 150$) with THR ($n = 184$).

Methods: Serial postoperative radiographs and medical records of dogs that underwent consecutive index cementless THR, with a single full cerclage wire placed distal to the femoral neck osteotomy line and proximal to the lesser trochanter, were reviewed for intraoperative and postoperative complications.

Results: No proximal femoral fractures occurred. No complications associated with the use of the cerclage wire were encountered. A fissure ($n = 1$) or fractures ($n = 2$) occurred near the tip of the femoral stem in three cases postoperatively. All three cases required plate and screw fixation. All dogs returned to subjectively normal function at home and all owners were satisfied with the outcome.

Conclusion: A single full cerclage wire may minimize the risk of a proximal femur fracture following cementless collared stem total hip replacement in dogs. No complications were encountered with the cerclage wire.

Clinical significance: Application of a cerclage wire is a simple and economically feasible procedure that requires minimal additional instrumentation, takes little time, and may decrease the risk of proximal femur fractures after cementless press-fit THR.

1 | INTRODUCTION

Canine total hip replacement (THR) is a successful and widely accepted surgical procedure.[1–5] As with most surgical procedures, complications can arise. One potentially catastrophic complication is proximal femur fracture. The incidence of intraoperative calcar cracks in humans was reported in 71 out of 4928 (1.44%) primary total hip arthroplasties.[6] Proximal fissure or calcar fracture in dogs has been reported[7–9] as a complication that requires revision surgery (Figure 1). The overall incidence of femur fractures as a complication of canine THR ranges from 2.9% to 13%.[7,8]

Fissures and fractures can occur during femoral medullary canal reaming and broaching. They may not always be detected. A fissure can propagate during early weight bearing to become a catastrophic fracture if axial forces exceed the structural integrity of the proximal femur. If a fissure is identified early, the cerclage wire can prevent widening and propagation of the fissure,

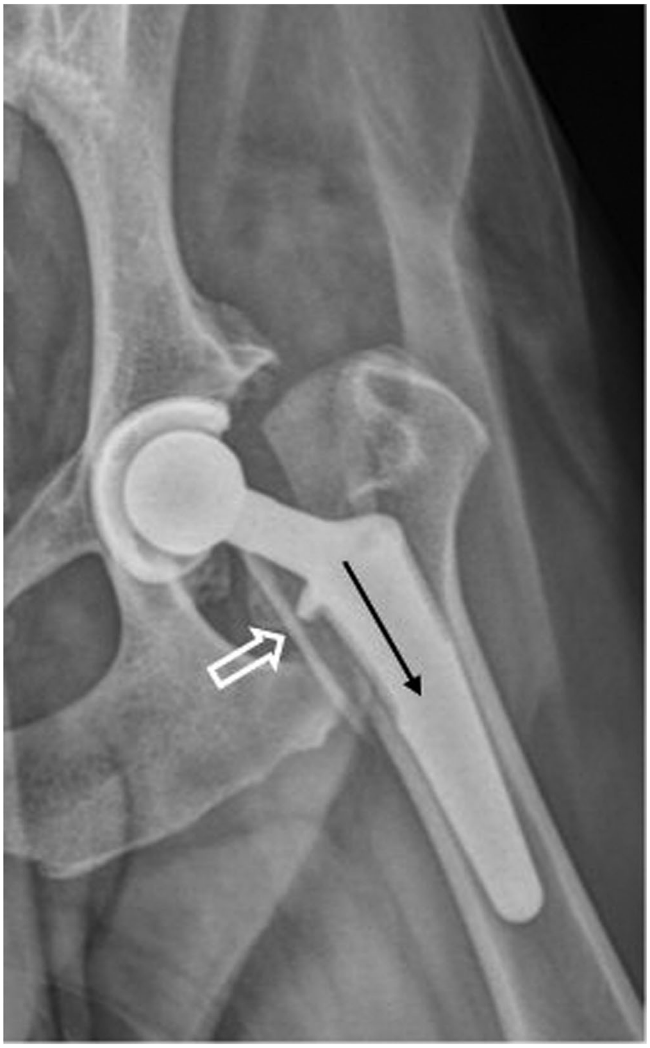

FIGURE 1 Proximal femoral fractures can occur following THR involving the calcar area. A triangular comminuted calcar fragment (white open arrow) can be seen, and stem subsidence is present (indicated by the black arrow). Stem retroversion often accompanies proximal femoral fractures

thereby decreasing the risk of subsequent subsidence and/or fracture. Plate and screw fixation may be used to prevent fissure development to a fracture in conjunction with cerclage wires. The proximal femur is also at risk of a fracture during cementless press-fit femoral stem implantation impaction if hoop strain is greater than the expansile load the bone can tolerate. Postoperatively, the weight-bearing load during convalescence can increase hoop strain and result in a catastrophic fracture (Figure 1).

It is appropriate to minimize the risk of a complication such as a proximal femoral fracture. This may be achievable with a prophylactic cerclage wire. This study was undertaken to evaluate the outcomes following application of a proximal femoral periprosthetic cerclage wire in 184 consecutive cementless total hip replacements in dogs.

2 | MATERIALS AND METHODS

2.1 | Criteria for case selection

Medical records of dogs undergoing THR by the same 2 surgeons were reviewed. Criteria for inclusion included THR with cementless biological fixation collared femoral stems (Electron Beam Melting Titanium BFX, EBM Ti BFX) (BioMedtrix, Whippany, New Jersey) and radiographic follow up. The stems were paired with cementless EBM BFX acetabular cups to eliminate the surgical technique and prosthesis type used as variables. All cases with a proximal femoral single loop cerclage wire were included. Animal demographics, THR indications, surgery times, and complications were recorded. Exclusion criterion included hips with less than 35 days of radiographic follow up, cases with less than 6 months of contact with the owners, and cases with a stem or cup other than the EBM Ti BFX stem and EBM BFX cup.

2.2 | Surgery planning

Standard digital orthogonal ventral-dorsal (VD) projection and lateral radiographs of the hips and pelvis were obtained in all dogs for preoperative planning. On the VD projection, the hips were in full extension with the femurs parallel to each other and parallel to the radiology tabletop. The hemipelves were superimposed on the lateral projection and the femurs were parallel in the sagittal plane but diverging at a 35-45 degree flexion angle. Radiographs were recalibrated for magnification using a 100 mm magnification marker placed on a magnification marker stand at the height of the femoral head. Templates were applied to predetermine implant sizes indicated. Dogs were considered candidates if a press-fit EBM Ti BFX collared stem was anticipated to be feasible, and if the dogs had no comorbidities that would be a contraindication for surgery.

2.3 | Prosthesis and instrumentation

The EBM Ti BFX femoral stem is manufactured by using electron-beam melting (EBM) technology with a titanium (ASTM F1472 Ti6Al4V) alloy to create a 3-dimensional porous structure for osteointegration. The cerclage wire (Securos Surgical, Friskdale, Massachusetts) was made of

316L stainless steel available in 18, 20, and 22 gauge diameters with a preformed loop for instrument application as previously described.[10]

2.4 | Surgical procedure

The surgical technique for implanting the EBM Ti BFX stem and BFX cup was the same in all hips. A cranial-lateral approach to the hip was used and a cementless stem and a cup were implanted as previously described to achieve secure implant fixation.[1] All procedures were performed by the same 2-surgeon team.

Femoral bed preparation for the implant was based on the preplanning optimum implant size, subjectively on cancellous bone envelope firmness and density, on the presence or absence of proximal femoral canal sclerotic bone lining the bed, and on the stem predrive distance. The predrive distance (Table 1) was measured with a caliper in 0.5 mm increments from the distal aspect of the collar to the proximal aspect of the osteotomy line at the calcar. The stem collar to osteotomy gap predrive distance was selected based on caliper measurements from prior THR experiences with highly variable cancellous bone density in dogs.

Impaction of the EBM Ti BFX stem was ceased when the position of the stem collar relative to the osteotomy line was no longer changing after several impactions, even if a gap remained between the collar and bone. At that point, stem fixation was considered to be press fit. A cerclage wire with a preformed loop was placed at least 1 mm distal to the osteotomy and proximal to the lesser trochanter when stem press fit was achieved. The wire diameter selection was empirical, based on surgeon discretion and body size.

Several (3-5) impactions on the stem were applied, in consideration of the viscoelasticity of bone, for final seating once the cerclage was in place. No further seating movement was observed in any cases. The predrive distance and remaining gap distance between the collar and bone at the calcar were recorded. The prosthetic femoral head with the appropriate neck length, selected by use of trial heads, was reduced into the cup and closure was routine.

TABLE 1 Case demographics and implants used

Age at surgery	Mean 4.03 years (range 0.58-12.8)	
Sex	F 5; FS 85; M 22; MN 72	
Bodyweight (kg)	Mean 32; range 16.4-59.5; median 30.5	
Body condition score	Mean 5.8/ 9; range 3-9/9; median 6	
Surgery side	Left: Right	88:96
THR indication	OA hip dysplasia (85% of total)	157
	Capital physeal fracture	14
	Traumatic luxation	6
	Traumatic round ligament tear/subluxation	4
	Previous acetabular fracture	1
	Femoral neck malpositioned	1
	Femoral neck fracture conversion	1
Surgery time (minutes)	Mean 77 (range 57-120)	77
Cup size	20 mm 13 mm head	8
	22 mm 14 mm head	45
	24 mm 17 mm head	77
	26 mm 17 mm head	34
	28 mm 17 mm head	17
	30 mm 17 mm head	3
Neck length (mm)	+0	43
	+1	4
	+3	62
	+5	24
	+6	37
	+7	3
	+9	11
Collared stem size	#6	42
	#7	65
	#8	42
	#9	26
	#10	9

Abbreviations: F, female; FS, female spayed; M, Male; mm, millimeters; MN, male neutered; OA, osteoarthritis.

2.5 | Radiographic evaluation

Postoperative VD and lateral radiographs positioned the same way as the preoperative radiographs were acquired with the dogs still under anesthesia. Cerclage wire positioning was evaluated to confirm that the wire was proximal to the lesser trochanter and not proximal to the osteotomy line at the calcar (Figure 2). Radiographs were evaluated for visible femoral fissures and fractures, for implant positioning, periosteal changes, and for any other possible complications. Radiographs were scheduled for 5-6 weeks, 12 months after surgery, and annually thereafter to assess for fractures or for any other complications. If dogs did not return for reevaluation within 13 months after the surgery date, owners were contacted with a reminder that the annual radiographs were due

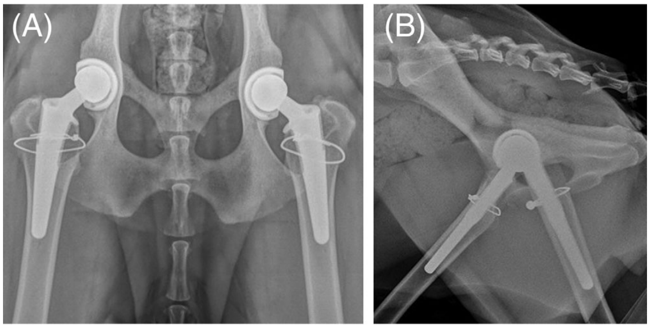

FIGURE 2 Staged bilateral THR with a proximal cerclage wire is shown in the ventral-dorsal and the lateral projections

TABLE 2 The stem predrive distance and remaining gap after press fit

Predrive mm	# Cases	Gap width mm	# Cases
2.5-2.9	1	Embedded ≤1 mm	2
3.0-3.9	17	0.0 mm (bone contact)	37
4.0-4.9	109	0.1-1.0 mm	75
5.0-5.9	39	1.1-2.0 mm	58
6.0-6.9	5	2.1-3.0 mm	10
7.0-7.1	1	>3.0 mm	2
Total	172	Total	184

Abbreviations: #, number; ≤, less than or equal to; >, greater than; mm, millimeters.

and queried about their dog's outcome at home. All images were archived for review. Two independent observers (SI and WL) evaluated all radiographs. The last radiographs acquired were the end point for evaluation for fractures. Operative and radiographic reports in the medical records were reviewed.

2.6 | Data collection and analysis

The data recorded from the medical records included the signalment, surgical details, and follow-up data of all dogs that had a THR with a collared EBM Ti BFX stem and BFX cup plus a cerclage wire implanted as described. The radiographs were examined separately by both surgeons evaluating any evidence of a proximal femoral fissure or fracture, or other complications. One observer (WL) collated and recorded data to minimize interobserver variability.[11]

The minimum duration of follow up for a fracture to occur was anticipated to be within 5 weeks but the longest follow-up period on record was collected to identify all recorded fractures. Data was collected for descriptive analysis but no statistical analysis was performed on the association of variables or complications.

3 | RESULTS

3.1 | Demographics, surgery indications, and implants

Records of 150 dogs with 184 THRs met the inclusion criteria (Tables 1 and 2). The indication for THR in 85% of the dogs was osteoarthritis secondary to hip dysplasia (Table 1). The application time of the single cerclage was less than 10 min in all cases. The population included 38 breeds of dogs; Labrador retriever ($n = 26$), German shepherd ($n = 40$), mixed breed ($n = 36$), and golden retriever ($n = 14$) dogs accounted for 116 (63%) of the THR hips. Preoperative general health testing was acceptable in all dogs and there were no comorbidities. The indications for surgery included osteoarthritis (OA) secondary to hip dysplasia, capital physeal fracture, traumatic hip luxation, subluxation secondary to a traumatic round ligament incomplete tear, basilar femoral neck fracture conversion, OA secondary to malunion of an untreated acetabular fracture, and malpositioned femoral neck secondary to a femoral corrective osteotomy. The cerclage wire diameters were 18, 20, and 22 gauges. The collared EBM Ti BFX stem sizes ranged from #6 to #10.

The stem collar to osteotomy gap predrive distance prior to first impaction and final press-fit positions was variable (Table 2). The mean stem predrive distance was recorded for the last 172 cases. The distances for the first 12 of the 184 were measured but not recorded. The mean stem predrive distance was 4.34 mm. The remaining gap left between the stem collar and bone at the medial aspect of the osteotomy line ranged from no gap with 0.5 mm of porous surface embedded in cancellous bone to a 3.1 mm gap between the porous surface of the collar and bone with a mean final gap of 1.25 mm.

A cerclage was used in both hips in 34 dogs with staged bilateral THR. A unilateral THR was performed in 100 dogs that received a cerclage. The remaining 16 dogs with staged bilateral THRs received a cerclage unilaterally (Table 3). The mean surgery time was 77.3 minutes (range 57-120 min).

3.2 | Radiographic findings

The mean radiographic follow-up time was 223 days (35 days-7.3 years). Forty-two dogs were followed for more than 1 year with the longest being followed for 7.3 years. All hips ($n = 184$) were examined radiographically at the earliest of 35 days to evaluate for short-term fissures or fractures. No proximal femoral fractures were identified

TABLE 3 Number of dogs with bilateral or unilateral hip replacement and cerclage wire use

Dogs with unilateral/bilateral THR with a cerclage	
Dogs – unilateral THR with a cerclage	100
Hips – unilateral THR with a cerclage	100
Dogs – bilateral THR with bilateral cerclage	34
Hips – Bilateral THR with bilateral cerclage	68
Dogs – Bilateral THR but unilateral cerclage	16
Hips – Unilateral cerclage/no cerclage contralateral THR	16
Total dogs in study	150
Total THR in study with a cerclage	184

Abbreviation: THR, total hip replacement.

FIGURE 3 The cerclage wire unfolded as noted (arrow) at the 6-week postoperative follow-up radiograph. No fractures occurred and function continued to be normal

on radiographs at that time, and none was identified in any dog on review of the follow-up radiographs. No cerclage wires failed or created radiographic evidence of bone pathology. One cerclage wire unfolded at the level of the preformed loop (Figure 3). The wire configuration did not change on subsequent radiographs, no fractures occurred, and the clinical outcome was excellent at 19 months after surgery.

3.3 | Outcomes and complications

No intraoperative or postoperative proximal femoral fissures or fractures occurred in the 184 THR cases with a proximal cerclage in place. Follow-up examination and radiographs of all dogs at a minimum of 35 days revealed no complications associated with the use of the cerclage wire. Phone contact at a minimum of 6 months found that all dogs resumed normal activity at home and all owners were subjectively satisfied with the outcome. A fissure ($n = 1$) and fractures ($n = 2$) occurred near the tip of the femoral stem postoperatively (Figure 4). All three cases required plate and screw fixation.

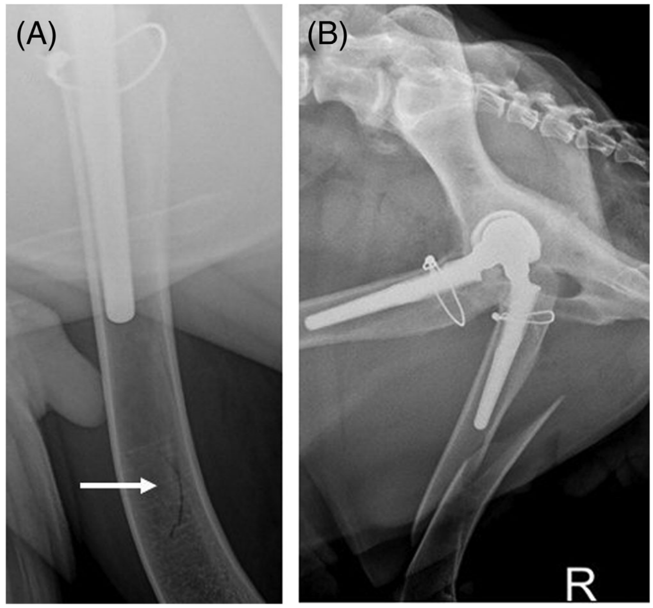

FIGURE 4 A cerclage wire proximal to the lesser trochanter does not prevent diaphyseal fissures or fractures. Fissures of the diaphysis (white arrow) distal to the stem were present when the dog presented 12 days after THR with an acute lameness after a fall in the back yard at home. A unilateral diaphyseal displaced fracture occurred in another dog that had cerclages placed during staged bilateral THR

An undersized femoral stem in a 47 kg dog with the collar resting entirely on cancellous bone subsided 6 mm and rotated to 12 degrees of retroversion. The cerclage wire remained in place and no fracture occurred despite the judgment error in stem-size selection (Figure 5). Revision surgery was not necessary because the clinical outcome was considered excellent at 23 months of follow up.

4 | DISCUSSION

4.1 | Incidence, causes, and prevention of proximal femur fissures and fractures

Total hip replacement complications include femoral fissures and fractures, which have been reported,[7,8] among other complications.[12] Proximal periprosthetic femoral

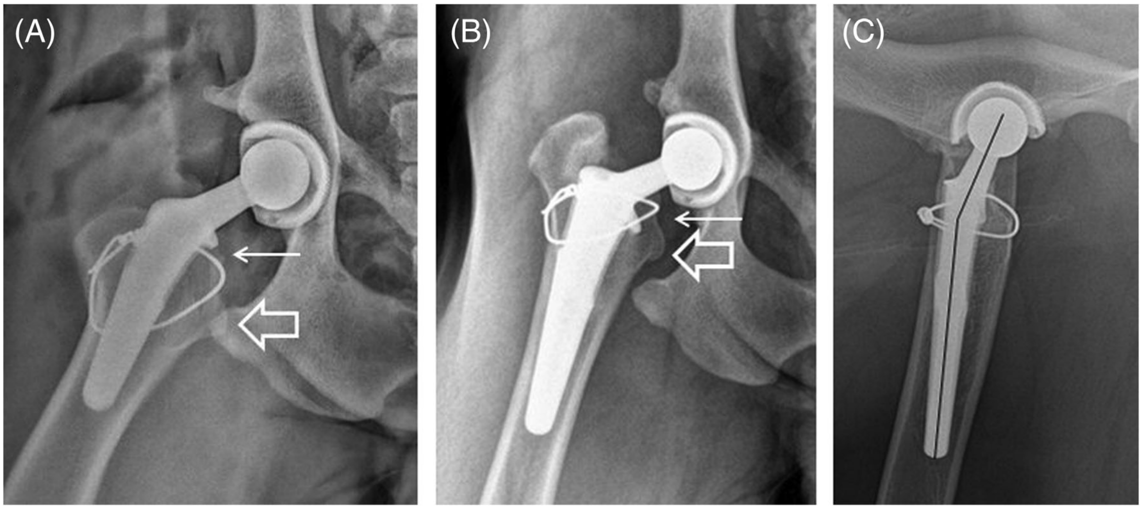

FIGURE 5 A view of the slightly abducted hip (A) illustrates the cerclage being distal to the osteotomy line (arrow) and proximal to the lesser trochanter (open arrow). A thick envelop of cancellous bone surrounds the stem indicating the stem was a size smaller than recommended. Six weeks (B) after THR, the stem is in subsidence, with the collar settled into cancellous bone. With the femoral condyles superimposed, the stem (C) also rotated into retroversion indicated by the black lines. Despite the subsidence, a fracture did not occur

fractures typically involve the calcar area on the medial cortex and lesser trochanter. This complication is compounded by subsequent acute femoral stem subsidence and instability. Rotation into retroversion and prosthesis laxity creating subluxation or luxation can accompany this complication. We were not able to compare the incidence of fissures or fractures in our cohort to dogs without proximal femoral cerclage wire but no proximal femoral fissures or fractures occurred in any of our cases that were implanted with a collared EBM Ti BFX femoral stem along with a cerclage wire placed proximal to the lesser trochanter.

The tapering cross-sectional geometry of femoral broaches and the femoral stems from proximal to distal is manually impacted with unmeasured forces into a similarly tapered but smaller femoral medullary canal implant bed preparation. As a result, fissures can occur in the proximal femur during femoral broaching and during impaction of the femoral stem. Fissures may go unnoticed and, if left unsecured, can propagate into a displaced fracture after surgery. Fissures and intraoperative fractures can also occur during broaching and stem impaction if these procedures are not coaxial with the femoral medullary canal. It is therefore important that the surgeon carefully inspect for fissures during both broaching and stem implantation. Fissures that occur or are present when stem impaction is complete should be appropriately managed, such as with cerclage application, prior to surgery closure. No fissures or fractures were observed intraoperatively. As the vast majority of proximal femur fractures or fissures occur intraoperatively or in the early postoperative period, we believe the minimum and mean radiographic follow-up times in our report were adequate to identify any postoperative fracture.

An approach to reduce the risk of proximal periprosthetic fracture not practiced in this study but under current evaluation by the authors is to place the cerclage after broaching before stem impaction. Theoretically, this option would lower the risk of fissure formation during femoral impaction and/or it might help stabilize undetected fissures. Additional studies are indicated to understand better why intraoperative fissures occur and how to avoid them.

In this study we were not able to draw statistical conclusions comparing our sample with a control group using the same operative technique but without a cerclage. Proximal femoral fractures were previously reported[7–9] and experienced by the authors (Figure 1). This complication was the impetus for the decision to add a proximal femoral cerclage wire even though the incidence is likely low.

We recommend placement of the cerclage to be proximal to the lesser trochanter and within 1-3 mm of the medial aspect of the femoral neck osteotomy line at the calcar. This location is where the hoop strain is the greatest around the circumference of the medullary canal.[13] If the cerclage is distal to the lesser trochanter, the benefits of cerclage wiring may be lost.

Hoop strain and angular forces create a predisposition to fissures and fractures. The peak torsional load to failure of ex vivo femora with adjunctive cerclage wire fixation failed at 20% greater peak torque than femora without adjunctive cerclage fixation.[14,15] The presence of a cerclage will increase resistance to stem subsidence. An in vitro mechanical study[16] looked at the resistance to subsidence in collarless femoral stems in which double-loop cerclage was placed after a fissure occurred. The load to initiate subsidence was found to be increased in femora with a double-loop cerclage compared to intact femora (mean 2379 N versus 1709 N). The mean relative subsidence for intact femora was 3.99 ± 2.09 mm versus 1.79 ± 2.99 mm with a cerclage in place. This relative subsidence was not statistically different between intact and stabilized specimens. Proximal femora cerclage and cables were also found to resist hoop stress in a human cadaver study using noncemented femoral stems.[17] Our findings support the theory that a cerclage wire aids in the prevention of periprosthetic fractures associated with press-fit cementless femoral stems.

Even though the coefficient of friction is high for collared EBM Ti BFX stems, minor subsidence ("settle") can and does occur.[4] Accumulation of data about the stem predrive distance and the gap remaining between the collar and bone (Table 1) may be useful to anticipate when press fit will be achieved and still have a short remaining gap between the collar and bone that will allow stem settle before collar contact, which could place additional load on the calcar. Mild stem settle may be favorable,[18] but stem settle could become excessive if press fit is not achieved at last impaction. If press fit is not achieved, excessive or unrestrained settle becomes subsidence (Figure 5). Loading on the implant during early weight bearing or inappropriate undersized implant selection can then produce excessive hoop stress on the proximal femur to potentially create a fissure or fracture. A cerclage is intended to reduce the risk of a fissure or fracture in these scenarios.

The use of cerclage wires to prevent fractures and to address fissures and fractures has been reported not only in dogs[14,16] but also in humans.[13,17] In a report on femur fracture risk factors in dogs with press fit cementless femoral stems, intraoperative fissure was addressed with cerclage in 3 cases.[8] None of the 3 dogs had femoral fracture later. Cerclage without fissure was used in 7 cases. No cases in which cerclage wire was applied had a femoral fracture after surgery. In that report, the presence of a fissure and use of cerclage were both too infrequent to analyze their influence on risk of femoral fracture.

Fissure and fractures distal to the lesser trochanter occurred in 3 cases in this report. A cerclage wire proximal to the lesser trochanter will not prevent diaphyseal fissures or fractures due to the difference in biomechanics in that area. Methods for the repair of fractures distal to the lesser trochanter have been reported.[9,15,19]

Stem impaction must be subjectively vigorous enough to achieve press fit, but not so excessive that it creates a fissure or fracture. The force of each impact and of end-point final impaction to achieve press fit is likely to vary among surgeons. The force of impaction necessary may vary when the surgeon has concerns about fissure risk or attempting to seat the stem deeper to improve final stem position. After stem implantation, a cerclage provides increased initial stability by preventing expansion of the cortical bone encircling the stem due to an undetected fissure or a fracture from hoop stress.[13,16] Initial instability due to a fissure or fracture can then compromise implant position, osteointegration, and long-term implant stability.

The EBM Ti BFX collar design is intended to optimize equal distribution of load transfer along the 45° osteotomy line.[4] If excessive load transfer to cortical bone does occur, the bone is predisposed to a fracture because the collar will not fail.[20] Resistance to excessive load transfer from the collar to bone that would create a fissure or fracture is dependent on cerclage strength, positioning, and accurate placement. Wire diameter and static tension were not categorized or based on objective measures. The parameters were empirical as if being placed during fracture fixation and repair.

The gap between collar and the osteotomy line varied from extremes of the collar embedded in cancellous bone ($n = 2$) to a >3.0 mm gap ($n = 2$) (Table 1). Both collars that embedded in cancellous bone were <1 mm deep with a predrive impaction distance >4.0 mm. The cancellous bone quality in both dogs was atypically soft and spongy instead of being normal, firm, or sclerotic. The stem collar resting on cancellous bone usually indicates that the stem is undersized, and a size larger stem possibly could be implanted. However, caution should be exercised if surgery preplanning reveals an unusually narrow medullary canal in the region into which the stem tip will be driven.

The final collar-bone gaps >3 mm were the result of an osteotomy line less than 45° coaxial to the femoral medullary canal. This minor technical error resulted in an additional 1-2 mm of calcar bone resection. In these dogs, the femoral stem shoulder was properly positioned, and it was estimated that the gap would have been <3.0 mm if the proper osteotomy line had been made. There was adequate space for cerclage placement proximal to the lesser trochanter.

The surgeon must be confident that the wire will not slide proximally and off bone after surgery. The wire cannot slide distally if it is in apposition to the medial flare of the proximal lesser trochanter. A double-loop cerclage is mechanically stronger than a single loop.[21] The double-loop cerclage application in this proximal location may require that a high enough femoral cut is made, or a portion of the lesser trochanter is removed with at least 3 mm of bone present to accommodate the wires.

4.2 | Press fit and avoidance of fissures and fractures

The gap between the collar on the stem and the bone along the correctly aligned osteotomy line at the calcar is a subjective visual indicator of when the press-fit moment is reached and is variable for each dog. When the gap distance is not decreasing, the stem is not moving, and impaction can cease. During stem impaction, the surgeon should strive to achieve the same level of stem insertion as demonstrated by the broach relative to the femoral neck cut osteotomy line. Measurement of the preimpaction predrive gap at the distal collar surface provides an objective reference for estimating the stem depth and remaining gap when press fit will be achieved. The firmness of the bone envelope around the perimeter of the bed preparation is variable and must be judged subjectively. In the future, a prospective study evaluating preoperative bone mineral density, 3-dimensional bone geometry, impaction forces applied, and fluoroscopic evaluation with correlation to the incidence of femur fissures and fractures may be helpful.[22]

4.3 | Alternatives to cerclage application

Alternative options exist to the use of a collared femoral stem in combination with cerclage application around the proximal femur to prevent proximal femoral fractures. Cement fixation of the femoral stem is prior generation technology that is an alternative to cementless stem fixation or if an intraoperative or postoperative fracture occurs. Hybrid cementless cup/cemented stem fixation is a viable option in dogs.[23] Cement fixation distributes load forces widely over the bone-cement interface to lower the risk of proximal femoral fractures, but diaphysis fractures beyond the cement mantle can still occur.[7] Another available instrumentation and implant system (Kyon Inc., Zurich, Switzerland) used with good long-term results has a very low incidence of proximal femoral fractures because it depends on screw fixation for stability, but femoral diaphysis fractures can still occur.[24] An interlocking lateral bolt system (BioMedtrix LLC, Whippany, NJ) was recently described, which aims to decrease fracture incidence resulting from excessive subsidence. This system requires a dedicated lateral bolt instrument set and the interlocking bolt inventory, which together adds expense and surgical time. The femoral stem used with this system is collarless, which is known to have subsidence complications.[4] It is reported that 1-2 mm of settle may also occur with a lateral bolt[25] but as much as 8 mm of subsidence has been documented with this implant system.[26,27] Collarless stem subsidence is the underlying reason to use a collared stem,[4] and proximal femoral fracture prevention is the reason to use a cerclage. The combination of a collar and cerclage accomplishes both goals and presents a favorable cost benefit scenario. Overall, the combined expense of a cerclage and the instrumentation for application is intuitively less than a costly THR revision surgery due to a proximal femoral fracture.

4.4 | Limitations

We did not compare the incidence, orientation, and natural course of proximal femoral fractures associated with THR when a cerclage was not implanted. Many variables would affect the incidence if cerclage wires were not used prophylactically.

This study has high internal validity related to lack of fractures when a cerclage is in place because all procedures were performed by the same 2 surgeons. Whether the results are generalizable when including less experienced surgeons is unknown. A multi-surgeon multi-institutional study to seek broad validity of this study is indicated.

A possible limitation of this study is the variable radiographic positioning during follow up in a practice clinical setting. The positioning of follow-up radiographs was not accepted until they mimicked the preoperative and postoperative radiographs, and the position of the cerclage was confirmed. Some owners were unwilling to return for radiographs beyond 35 days, and it is possible that some dogs had femoral fissures that went undetected.

Multicenter prospective randomized studies of cerclage application versus nonapplication may be warranted but risk of a fracture would be a factor for the animal and an explanation would require preoperative full disclosure to the owner. Resolution of fracture complications would be difficult to justify if a cerclage was not implanted solely for randomization reasons. However, cerclage wire application is not a completely benign process as it requires additional soft tissue dissection and implants.

In conclusion, a proximal femoral fracture did not occur after any THR with a collared EBM Ti BFX femoral stem along with a cerclage wire placed proximal to the lesser trochanter. No revision surgery was required for proximal femoral fractures. Application of a cerclage wire took little time and was a cost-effective procedure that did not require dedicated instrumentation, and the outcomes confirmed minimal risk associated with the wire itself.

ACKNOWLEDGMENTS

Author Contributions: Israel SK, DVM, DACVS: Participation in conceptual design, data collection, and analysis. Drafting of the manuscript. Major revisions and final editing work. Liska WD, DVM, DACVS: Participation in conceptual design, data collection, and analysis. Drafting of the manuscript.

The authors thank the many dog owners for their confidence and trust that made it possible for their suffering companions to receive a pain-free, fully functioning hip. They also wish to thank Ned F. Kuehn, DVM, MS, DACVIM for reviewing the manuscript, and Professor Howard D. Thames Jr. PhD, FASTRO, MDACC for statistical analysis.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

REFERENCES

1. Peck JN, Marcellin-Little DJ. *Advances in Small Animal Total Joint Replacement*. Wiley Blackwell; 2013.
2. Budsberg SC, Chambers JN, van Lue SL, Foutz TL, Reece L. Prospective evaluation of ground reaction forces in dogs undergoing unilateral total hip replacement. *Am J Vet Res*. 1996;57:1781-1785.
3. Olmstead ML, Hohn RB, Turner TM. A five-year study of 221 total hip replacements in the dog. *J Am Vet Med Assn*. 1983;183:191-194.
4. Liska WD, Doyle ND. Use of an electron beam melting manufactured titanium collared cementless femoral stem to resist subsidence after canine total hip replacement. *Vet Surg*. 2015;44:883-894.
5. Liska WD, Israel SK. Morbidity and mortality following total hip replacement in dogs. *Vet Comp Ortho Traumatol*. 2018;31:218-221.
6. Park CW, Lim SJ, Ye DH, Park YS. Outcomes of cerclage cabling for intraoperative calcar cracks in cementless total hip arthroplasty using broach-only, tapered wedge stems. *J Arthroplasty*. 2020;35:3002-3009.
7. Liska WD. Femur fractures associated with canine total hip replacement. *Vet Surg*. 2004;33(2):164-172.
8. Ganz SM, Jackson J, VanEnkevort B. Risk factors for femoral fracture after canine press-fit cementless total hip arthroplasty. *Vet Surg*. 2010;39(6):688-695.
9. Kidd SW, Preston CA, Moore GE. Complications of porous-coated press-fit cementless total hip replacement in dogs. *Vet Comp Orthop Traumatol*. 2016;29:402-408.
10. Liska WD. Wires in long bone fracture repair. In: Slatter DH, ed. *Textbook of Small Animal Surgery. Vol II*. W B Saunders; 1985:2003-2014.
11. Kramhoft M, Gehrchen PM, Bodtker S, Wagner A, Jensen F. Inter and intra-observer study of radiographic assessment of cemented total hip arthroplasties. *J Arthroplasty*. 1996;11:272-276.
12. Liska WD, Dyce J. Total hip replacement. In: Griffon D, Hamaide A, eds. *Complications in Small Animal Surgery*. Wiley Blackwell; 2016:778-833.
13. Fishkin Z, Han SM, Ziv I. Cerclage wiring technique after proximal femoral fracture in total hip arthroplasty. *J Arthroplasty*. 1999;14:98-101.
14. Christopher SA, Kim SE, Roe S, Pozzi A. Biomechanical evaluation of adjunctive cerclage wire fixation for the prevention of periprosthetic femur fractures using cementless press-fit total hip replacement. *Vet J*. 2016;214:7-9.
15. Pozzi A, Peck JN, Chao P, Choate CJ, Barousse D, Conrad B. Mechanical evaluation of adjunctive fixation for prevention of periprosthetic femur fracture with the Zurich cementless total hip prosthesis. *Vet Surg*. 2013;42(5):529-534.
16. McCulloch RS, Roe SC, Marcellin-Little DJ, Mente PL. Resistance to subsidence of an uncemented femoral stem after cerclage wiring of a fissure. *Vet Surg*. 2012;41:163-167.
17. Herzwurm PJ, Walsh J, Pettine KA, Ebert FR. Prophylactic cerclage: a method of preventing femur fracture in uncemented total hip arthroplasty. *Orthopedics*. 1992;15(2):143-146.
18. Whiteside LA, Amador D, Russell K. The effects of the collar on total hip femoral component subsidence. *Clin Orthop Relat Res*. 1988;231:120-126.
19. Carvajal JL, Kim SE, Pozzi A. Use of a cerclage cable-plate system to stabilize a periprosthetic femoral fracture after total hip replacement in a dog. *Vet Surg*. 2019;48:437-443.
20. BioMedtrix: BFX titanium EBM femoral stem. Internal technical report #120630 Fully porous titanium collar: Ultimate strength. June 2012.
21. Roe SC. Mechanical characteristics and comparisons of cerclage wires: introduction of the double-wrap and loop/twist tying methods. *Vet Surg*. 1997;26:310-316.
22. Bernatz JT, Brooks AE, Squire MW, Illgen RI, Binkley NC, Anderson PA. Osteoporosis is common and undertreated prior to total joint arthroplasty. *J Arthroplasty*. 2019;34:1347-1353.
23. Gemmill TJ, Pink J, Renwick A, et al. Hybrid cemented/cementless total hip replacement in dogs: seventy-eight consecutive joint replacements. *Vet Surg*. 2011;40:621-630.
24. Hummel DW, Lanz OI, Were SR. Complications of cementless total hip replacement. A retrospective study of 163 cases. *Vet Comp Orthop Traumatol*. 2010;23:424-432.
25. Buks Y, Wendelburg KL, Stover SM, Garcia-Nolen TC. The effects of interlocking a universal hip cementless stem on implant subsidence and mechanical properties of cadaveric canine femora. *Vet Surg*. 2016;45:155-164.
26. Mitchell MM, Hudson CC, Beale BS. A retrospective evaluation of femoral stem subsidence in patients undergoing cementless total hip replacement. *Vet Comp Orthop Traumatol*. 2018;31(S 02):A1-A25. doi:10.1055/s-0038-1668182
27. Mitchell MM, Hudson CC, Beale BS. Comparison of femoral stem subsidence between three types of press-fit cementless total hip replacement in dogs. *Vet Surg*. 2020;49:787-793.

How to cite this article: Israel SK, Liska WD. Outcome of canine cementless collared stem total hip replacement with proximal femoral periprosthetic cerclage application: 184 consecutive cases. *Veterinary Surgery*. 2022;51(2):270-278. doi:10.1111/vsu.13740