Use of a cerclage cable-plate system to stabilize a periprosthetic femoral fracture after total hip replacement in a dog

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Article title: Use of A Cerclage Cable-Plate System to stabilize~~for Stabilization of~~ a Periprosthetic Femoral Fracture Following Total Hip Replacement in a Dog.

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Abstract:

Objective: To ~~demonstrate~~ report the successful use of cerclage cables around the periprosthetic region of a femoral fracture after~~following~~ total hip replacement (THR) in a dog ~~where sufficient~~ with bone stock ~~may not be available~~too limited for other methods of fixation.

Study Design: Case report

Animal: 6-year-old, Male Neutered, Golden Retriever.

Methods: ~~Acute onset of lameness due to failure~~ Locking plate fixation of a Type-B1 diaphyseal periprosthetic femoral fracture failed 14 days after cementless THR, and 6 days after initial femoral fracture repair. THR implants seemed unchanged on radiographs, but lateral retraction of the screw-plate construct from the proximal segment was evident. Bone stock was assessed as insufficient for adequate screw purchase, prompting revision of the fixation with cerclage cable fixation of the proximal segment; the cables were anchored to the original locking plate construct with threaded positioning pins that screwed into the locking holes. ~~Locking plate fixation failure for a Type-B1 diaphyseal periprosthetic femoral fracture that occurred 14 days after cementless THR, and 6 days after femoral fracture repair. Radiographs revealed stable positions of the THR implants, but screw loosening and separation of the plate fixation from the proximal segment was evident. Given the lack of bone stock for adequate screw purchase, revision of the fixation was performed by using cerclage cable fixation of the proximal segment;~~

~~the cables were anchored to the original locking plate construct with threaded positioning pins that screwed into the locking holes.~~

Results: Acceptable union was documented on radiographs by 3 months after revision. No lameness and good range of motion of the hip were observed on clinical examination 13 months after surgery. Radiographs at 13 months documented static implant positioning, and remodeling at the fracture site.~~Acceptable union was documented on radiographs by 3 months following revision. Clinical evaluation 13 months after revision of the failed fracture repair demonstrated no lameness and good range of motion of the hip.~~

Conclusion: Use of a cable-plate construct to stabilize a Type-B1 periprosthetic femoral fracture led to successful long-term outcome in this dog.

Clinical significance: Use of a cable-plate construct may be considered to treat Type-B1 periprosthetic femoral fractures with limited bone stock

Introduction

Total Hip Replacement (THR) is a reliable treatment option for a variety of conditions including canine hip dysplasia, hip osteoarthritis, and traumatic coxo-femoral luxation.[1-3] However, complications including septic or aseptic implant loosening, luxation, infection, periprosthetic femoral fractures (PFF), and implant failure are well documented following THR in dogs, and typically require surgical revision.[4-8]

Femoral fractures following THR in dogs has been reported in 1.5-13% of cases, with most fractures occurring within the first 4 months after surgery.[7-10] Risk factors reported for PFF include older age, cortical thinning, previous THR in contralateral limb, and dogs with lower canal flare index (CFI).[7-11] Iatrogenic fissure fractures of the femur during the reaming process of press-fit systems are routinely stabilized using cerclage wires with high success.[8-10] In contrast, post-operative PFF are typically far more difficult to manage. Due to the anatomy of the proximal femur and the inherent design of most intramedullary femoral implants, repair options are limited, and adequate screw purchase may not be available in the proximal femur for plate-screw fixation. The increasing prevalence in PFF reported in humans has led to the development of several guidelines and a plethora of adjunctive fixation systems for the specific purpose of facilitating fracture repair in these challenging cases.[12-14] The incorporation of allograft struts, specialized plates, and cerclage cable-plate constructs are routinely utilized.

In particular, stainless steel cerclage cables are often incorporated in conjunction with plate-screw constructs to prevent screw-pull out, increase stability, and allow fixation of the plate constructs around the proximal femur occupied by femoral stems where screw purchase is limited.[14] Implementation of cable-plate systems in veterinary medicine has only been reported in a single horse.[15] The purpose of this case report is to report thedescribe successful use of cerclage cables around the periprosthetic region of a femoral fracture after total hip replacement (THR) in a dog with bone stock too limited for other methods of fixation.the successful use of a cable-plate system for the treatment of a failed PFF repair using conventional locking plate constructs in a dog.

Clinical Report

A 6-year-old, male neutered, Golden Retriever presented to the University of Florida College of Veterinary Medicine Small Animal Hospital for an evaluation of a progressive right hind limb lameness of several years duration. Additional medical history included a left cementless THR (BFX; BioMedtrix, Whyppany, NJ) (size 26mm acetabular cup, size 10 femoral stem, and 17mm +3 femoral head, with 4 cerclage wires due to intraoperative fissuring of the femur) performed 3 years prior to presentation. Orthopedic examination revealed a body condition score of 6/9, a grade 2/5,[16] right hind limb lameness, moderate muscular atrophy of the right hind limb, and moderate pain on extension and abduction of the right hip.

Pre-operative radiographs revealed moderate right coxo-femoral osteoarthritis, moderate to severe right coxo-femoral subluxation, moderate right pelvic limb muscular atrophy, and static left THR implants. The CFI of the right femur was 1.93.[10] Clinical signs were attributed to severe hip dysplasia and osteoarthritis, and a right cementless THR was performed using 26 mm cementless acetabular cup, size 9 collared cementless titanium femoral stem and 17mm +3 femoral head (BFX; BioMedtrix).

During early preparation of the femoral canal, a fissure fracture developed at the cranio-medial aspect of the proximal femoral metaphysis and diaphysis. Seven 1.0 mm single loop cerclage wires were placed along and beyond the length of the fissure. The remainder of the procedure was completed routinely, and post-operative radiographs revealed satisfactory implant size and alignment (Fig. 1a, 1b). Standard multi-modal analgesic protocols were followed (intravenous [IV] constant rate infusion of Hydromorphone (Dilaudoid; Knoll Pharma), Lidocaine 2% (Vet One; Biose, ID) and Ketamine Hydrochloride (Putney; Lostock Gralam, Northwich, UK). Cefazolin (30mg/kg IV) was administered commencing one hour prior to surgery and every 90 minutes until the end of surgery, then every 6 hours for 24 hours following surgery. Postoperative medications upon discharge consisted of oral 4.0 mg/kg tramadol hydrochloride every 8 hours, oral 2.0 mg/kg Carprofen (Zoetis; Parsippany, NJ) every 24 hours, and oral 29.5 mg/kg Cephalexin (Keflex; Teva Pharmaceuticals, Petach Tikva, Israel) every 12 hours for 14 days.[17]

One week later, the dog presented for an acute onset of a grade 4/5,[16] right hind limb lameness after slipping at home. Physical exam revealed swelling and pain over the surgical site. Radiographs revealed a Vancouver Type B1 PFF, characterized by a stable well-fixed stem with the fracture involving the distal tip of the stem at the mid-diaphysis.[7,13] There was mild comminution, and cranial and medial angulation of the major distal fracture segment, with a cerclage wire present within the fracture site. All remaining implants were deemed to be unchanged when compared to the immediate post-operative radiographs (Fig. 1c,1d).

Fracture repair was performed with plate fixation. A lateral approach was made to the femur, the unstable cerclage wire at the fracture site was removed, and direct reduction of the fracture was achieved with bone-holding forceps. A 14-hole 3.5 mm broad locking compression plate (DePpuy Synthes; West Chester, PA) was applied in bridging fashion (Fig 2a). The plate was contoured and applied to the lateral surface of the femur. One bi-cortical 3.5 mm locking screw and one 3.5 mm bi-cortical cortical screw was used in the greater trochanter, with one mono-cortical 3.5 mm cortical screw in the proximal metaphysis. Three bi-cortical 3.5 mm locking screws and one 3.5 cortical screw were used in the distal segment. Attempts to engage the trans-cortex of the proximal metaphysis with the proximal screws were not successful due to interference from the femoral stem. Deep-tissue samples and the removed cerclage wire were submitted for bacterial culture and sensitivity, which showed no evidence of growth. The same standard multi-modal analgesic and anti-microbial protocols as the original THR procedure were followed. Immediate post-operative radiographs revealed acceptable reduction and implant placement; however, the proximal screws were deemed short and there was immediate concern regarding the security of the proximal segment (Fig. 2a).

The dog was hospitalized during the initial convalescent period. On the sixth day of hospitalization, the dog's ambulatory status declined, and a grade 3/5[16] lameness of his operated limb was noticed. Radiographs revealed lateral retraction of the screw-plate construct from the bone, and a new short fracture line (Fig. 2b).

At this time, all radiographs were reviewed, and progressive osteopenia of the right femur was noted, which was most evident when comparing radiographs performed three years prior to immediately prior to right THR (Fig. 3a,3b). Systemic causes of osteopenia were investigated after a serum ionized calcium concentration from a point of care blood analyzer (iSTAT, Abbott; Princeton, NJ) was found to be elevated at 1.41 mmol/L (reference range: 1.18-1.35 mmol/L). However, serum ionized calcium, parathyroid hormone, Vitamin D, and parathyroid hormone-related protein performed by Michigan State University Veterinary Diagnostic Laboratory were all within normal limits. Total Thyroxine 4, Thyroid Stimulating Hormone, Free Thyroxine 4 results (1.45 µg/dL, 0.096ng/mL, 1.07ng/dL respectively), were also all within normal limits.

Revision surgery was planned to incorporate cerclage cable fixation to the failed proximal construct segment. An approach was made to the proximal femur. The proximal locking screw was removed and tightening of the most proximal cortical screw in the greater trochanter was attempted in order to restore reduction; however, the screw hole was stripped. This cortical screw was then also removed. Two threaded positioning pins (DePpuy Synthes) were placed in the two most proximal screw holes, and two 1.7 mm stainless steel cerclage cables (DePpuy Synthes) were directed through the positioning pins, placed circumferentially around the femur, then threaded through a pre-placed metallic crimp (Fig. 4). A cable tensioner (DePpuy Synthes) was used to sequentially tighten both cables to approximately 40 kg of tension, thereby compressing the proximal segment to the plate. The crimps were compressed to lock the cables in place. A third cerclage positioning pin and 1.7 mm cable was placed in the 5th screw hole and secured in similar fashion. The remaining proximal cortical screw was then tightened. A cancellous autograft was harvested from the right proximal humerus and was transplanted into the fracture site prior to routine closure. Post-operative radiographs revealed acceptable reduction and implant placement (Fig 5). Similar standard multi-modal analgesic protocols were followed as in the previous two surgical procedures. The dog was discharged from the hospital 7 days after surgery.

At 30 days following the second revision, the dog was fully weight bearing on the right hind limb with no observable lameness. Radiographs showed documented static implant positioning, and remodeling at the fracture site consistent with healing. The dog was reassessed at 12 weeks, 24 weeks, and 13 months after PFF revision. No further lameness of the operated limb was detected. The implants in the right femur remained in position and clinical union at the fracture site was confirmed by 12 weeks (Fig 6). The dog was allowed to progressively return to normal activity over a 1 month period. Upon clinical evaluation 13 months after revision of the failed fracture repair, the dog had no lameness and good range of motion of the hip; owners reported that the dog had returned to normal activity levels and excellent limb use was reported. Radiographs at 13 months documented static implant positioning, and progression of remodeling at the fracture site (Fig 7).

Discussion

This case report documents the successful treatment of a periprosthetic femoral fracture after THR with a cable-plate system in a dog. These fractures are challenging because bone stock in the proximal femur may be too limited for proper bone plate-screw fixation. Treatment guidelines and available treatment options for PFF in dogs are currently limited.[7,10,18,19] The difficulty achieving sufficient screw purchase due to crowding of the proximal femoral segment by the femoral stem was reflected in this case, where implant failure was noted within one week of repair using a traditional plate-screw construct.

The press-fit cementless femoral stem was elected due to a successful arthroplasty of the contralateral side using the same system three years prior, current non-geriatric age, and suitable CFI. [10] The severity of osteopenia present was initially underestimated, and strategies to prevent PFF and subsequent implant failure could have been implemented if recognized earlier. Progressive osteopenia of the right femur was evident upon comparison of cortical thickness from radiographs performed three years prior to radiographs immediately prior to right THR (Fig 3a, 3b). Furthermore, the fissure fractures encountered early in the broaching process should have alerted suspicion to the poor mechanical integrity of the femur. The probable cause of osteopenia was determined to be due to chronic disuse given the lack of evidence for endocrinopathies compromising

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Kommentar [JC2]: Reformatted to remove subordinate clause

Kommentar [JC3]: Reformatted to remove subordinate clause bone quality. ~~While a~~A collared stem was chosen to prevent subsidence and excessive stress on the proximal metaphysis;~~,~~[20] however, prophylactic plate placement should have been strongly considered at the time of initial arthroplasty.[19] A cemented femoral stem could have been pursued, although fractures due to cortical thinning have also been reported following cemented THR.[7] Alternatively, continued conservative management for hip dysplasia rather than THR may have been a reasonable option given the complexity of the case.

Periprosthetic fracture repair is also a major clinical challenge in the human field.[12-14] Although no consensus of optimal technique or fixation system is currently acknowledged, supplemental fixation to standard screw-plate internal fixation is often necessary and routinely pursued.[21-23] Screw-plate constructs provide greater mechanical stability when compared to cable-plate systems in biomechanical analyses using healthy human femurs and femoral models.[12,21-23] However, cable-plate constructs may be a more suitable option for cases with poor bone quality and/or limited bone stock preventing adequate screw purchase,[24] as screws may act as stress risers or pull out during cyclic loading when in proximity to cement mantle or stem.[25]

Treatment options were limited in the case reported here. Additional screws in the lateral plate could not have been used due to the presence of cerclage wiring, presence of a large femoral stem, as well as poor bone quality. Fortunately, the bone plate system used for the initial fracture repair was compatible with an orthopedic cable system (DePuy Synthes). The system utilizes 316L stainless steel, titanium alloy, and L605 cobalt chromium alloy cerclage cables that anchor to the plate and are placed under tension

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around the bone with the aid of a dedicated tensioner device. The ability to sequentially tighten the cable by gradually applying tension was particularly useful in achieving reduction of the fracture. Although screw-plate constructs have been shown to provide greater mechanical stability when compared to cable-plate systems in biomechanical analyses using healthy human femurs and femoral models,[12,21-23] cable-plate constructs may be a more suitable option for cases with poor bone quality and/or limited bone stock preventing adequate screw purchase.[24] When in proximity to cement mantle or stem, screws may act as stress risers, or pull out during cyclic loading.[25]
The placement of circumferential cables around the trochanteric region enabled a satisfactory level of fixation and stability without creating further defects in the underlying bone. Successful clinical use of cable-plate systems has also been reported for the treatment of Type B1 PPF in humans, which is a common complication in geriatric populations with poor bone quality.[26,27] Contraindications to using cable-plate constructs alone include loose or mal-aligned prostheses, in which arthroplasty revision is preferred, as well as previous periosteal stripping or devascularization, as compression from the cables may theoretically further delay bony union.[28,29]

Alternative treatment options for this case included the addition of an orthogonal plate.[30] However, this would have been a poor choice due to bone stock availability and quality. An additional plate would have likely achieved only monocortical fixation of the proximal segment, and caused increased morbidity and tissue trauma due to the additional exposure required for the placement of another plate. Successful fixation with string-of-pearls (SOP) plates has been described in dogs,[18] but would have potentially led to recurrent implant failure in this case. ~~Although t~~Temporary explantation and placement of a cemented stem could have allowed placement of bi-cortical screws in the periprosthetic region, but this was not favored due to the poor condition of the existing bone. The last available option involved permanent explantation in order to increase amount of available bone for fixation.

The limitations of this report are inherent to the nature of being a single case. The outcome in this case ~~shows~~ documents the use of a cable-plate construct to successfully stabilize a Type-B1 PFF in a dog despite lack of life-long follow-up. The sequence of complications seen in this case suggests that pre-existing osteopenia requires a different approach from standard fractures. The poor mechanical characteristics of osteopenic bone may not offer enough pull-out strength for plate and screw fixation only, and a cable-plate construct may be indicated in these cases. Further studies and case inclusions are required to better define appropriate case selection in order to maximize treatment success in dogs with PFF following THR.

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The authors would like to acknowledge DeP~~p~~uy Synthes for providing surgical equipment used in this report.

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References

1. Pozzi A, Kowaleski MP, Dyce J, Johnson KA. Treatment of traumatic coxo-femoral luxation by cemented total hip arthroplasty. *Vet Comp Orthop Traumatol*. 2004;17(4):198-203. doi:10.1055/s-0038-1632820

2. Jankovits DA, Liska WD, Kalis RH. Treatment of Avascular Necrosis of the Femoral Head in Small Dogs with Micro Total Hip Replacement. *Vet Surg*. 2012;41(1):143-147. doi:10.1111/j.1532-950X.2011.00925.x

3. Allen MJ. Advances in total joint replacement in small animals. *J Small Anim Pract*. 2012;53(9):495-506. doi:10.1111/j.1748-5827.2012.01264.x

4. Dyce J, Olmstead ML. Removal of Infected Canine Cemented Total Hip Prostheses Using a Femoral Window Technique. *Vet Surg*. 2002;31(6):552-560. doi:10.1053/jvet.2002.34670

5. Forster KE, Wills A, Torrington AM, et al. Complications and Owner Assessment of Canine Total Hip Replacement: A Multicenter Internet Based Survey. *Vet Surg*. 2012;41(5):545-550. doi:10.1111/j.1532-950X.2012.01015.x

6. Hummel DW, Lanz OI, Werre SR. Complications of cementless total hip replacement. *Vet Comp Orthop Traumatol*. 2010;23(6):424-432. doi:10.3415/VCOT-09-07-0071

7. Liska WD. Femur Fractures Associated with Canine Total Hip Replacement. *Vet Surg*. 2004;33(2):164-172. doi:10.1111/j.1532-950X.2004.04024.x

8. Kidd SW, Preston CA, Moore GE. Complications of porous-coated press-fit cementless total hip replacement in dogs. *Vet Comp Orthop Traumatol*. 2016;29(5):402-408. doi:10.3415/VCOT-15-07-0116

9. Townsend S, Kim SE, Pozzi A. Effect of stem sizing and position on short-term complications with canine press fit cementless total hip arthroplasty. *Vet Surg*. 2017;46(6):803-811. doi:10.1111/vsu.12666

10. 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. doi:10.1111/j.1532-950X.2010.00694.x

11. Guerrero TG, Montavon PM. Zurich Cementless Total Hip Replacement: Retrospective Evaluation of 2nd Generation Implants in 60 Dogs. *Vet Surg*. 2009;38(1):70-80. doi:10.1111/j.1532-950X.2008.00466.x

12. Dennis MG, Simon JA, Kummer FJ, Koval KJ, DiCesare PE. Fixation of periprosthetic femoral shaft fractures occurring at the tip of the stem: A biomechanical study of 5 techniques. *J Arthroplasty*. 2000;15(4):523-528. doi:10.1054/arth.2000.4339

13. Buttaro MA, Farfalli G, Núñez MP, Comba F, Piccaluga F. Locking compression plate fixation of Vancouver type-b1 periprosthetic femoral fractures. *J Bone Joint Surg Am*. 89(9):1964-1969. doi:10.2106/JBJS.F.01224

14. Haddad FS, Marston RA, Muirhead-Allwood SK. The Dall-Miles cable and plate system for periprosthetic femoral fractures. *Inj-Int J CARE Inj*. 1997;28:445-447.

15. Bolt DM, Burba DJ. Use of a dynamic compression plate and a cable cerclage system for repair of a fracture of the radius in a horse. *J Am Vet Med Assoc*. 2003;223(1):89-92. doi:10.2460/javma.2003.223.89

16. Impellizeri JA, Tetrick MA, Muir P. Effect of weight reduction on clinical signs of lameness in dogs with hip osteoarthritis. *J Am Vet Med Assoc*. 2000;216(7):1089-1091. doi:10.2460/javma.2000.216.1089

17. Brown DC. Wound infections and antimicrobial use. In: Veterinary Surgery: Small Animal, 1st edn. 2011. Eds Tobias KM, Johnston SA, St. Louis, MO, USA. p137

18. Fitzpatrick N, Nikolaou C, Yeadon R, Hamilton M. String-Of-Pearls Locking Plate and Cerclage Wire Stabilization of Periprosthetic Femoral Fractures after Total Hip Replacement in Six Dogs. *Vet Surg*. 2012;41(1):180-188. doi:10.1111/j.1532-950X.2011.00870.x

19. 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. doi:10.1111/j.1532-950X.2013.12018.x

20. 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(7):883-894. doi:10.1111/vsu.12353

21. Lever JP, Zdero R, Nousiainen MT, Waddell JP, Schemitsch EH. The biomechanical analysis of three plating fixation systems for periprosthetic femoral fracture near the tip of a total hip arthroplasty. *J Orthop Surg*. 2010;5:45. doi:10.1186/1749-799X-5-45

22. Dennis MG, Simon JA, Kummer FJ, Koval KJ, Di Cesare PE. Fixation of Periprosthetic Femoral Shaft Fractures: A Biomechanical Comparison of Two Techniques. *J Orthop Trauma*. 2001;15(3):177.

23. Griffiths JT, Taheri A, Day RE, Yates PJ. Better Axial Stiffness of a Bicortical Screw Construct Compared to a Cable Construct for Comminuted Vancouver B1 Proximal Femoral Fractures. *J Arthroplasty*. 2015;30(12):2333-2337. doi:10.1016/j.arth.2015.06.060

24. Lenz M, Perren SM, Gueorguiev B, et al. A biomechanical study on proximal plate fixation techniques in periprosthetic femur fractures. *Injury*. 2014;45:S71-S75. doi:10.1016/j.injury.2013.10.027

25. Graham SM, Moazen M, Leonidou A, Tsiridis E. Locking plate fixation for Vancouver B1 periprosthetic femoral fractures: a critical analysis of 135 cases. *J Orthop Sci*. 2013;18(3):426-436. doi:10.1007/s00776-013-0359-4

26. Sandhu R, Avramidis K, Johnson-Nurse C. Dall-Miles Cable and Plate Fixation System in the Treatment of Periprosthetic Femoral Fractures: A Review of 20 Cases. *J Orthop Surg*. 2005;13(3):259-266. doi:10.1177/230949900501300308

27. Old AB, McGrory BJ, White RR, Babikian GM. Fixation of Vancouver B1 peri-prosthetic fractures by broad metal plates without the application of strut allografts. *J Bone Joint Surg Br*. 2006;88-B(11):1425-1429. doi:10.1302/0301-620X.88B11.17749

28. Froberg L, Troelsen A, Brix M. Periprosthetic Vancouver type B1 and C fractures treated by locking-plate osteosynthesis. *Acta Orthop*. 2012;83(6):648-652. doi:10.3109/17453674.2012.747925

29. Russo M, Malekzadeh AS, Hampton C, Hymes R, Schwartzbach C, Schulman J. Reversed Contralateral LISS Plate for Vancouver B1 Periprosthetic Femoral Shaft Fractures. *Orthopedics*. 2015;38(6):e467-e472. doi:10.3928/01477447-20150603-53

30. Lenz M, Stoffel K, Gueorguiev B, Klos K, Kielstein H, Hofmann GO. Enhancing fixation strength in periprosthetic femur fractures by orthogonal plating—A biomechanical study. *J Orthop Res*. 2016;34(4):591-596. doi:10.1002/jor.23065

Figure Legends

Fig. 1 A) Craniocaudal and B) mediolateral projection radiographs of the right femur following THR. There is appropriate size and positioning of prosthetic femoral stem, femoral head, and acetabulum. Cerclage wires were placed around the proximal and mid-diaphysis of the right femur to address a femoral fissure that occurred during broaching. C) craniocaudal and D) mediolateral projection radiographs performed 1 week after THR revealed a comminuted mid-diaphyseal fracture characterized by cranial and medial angulation of the major distal fracture segment, with a cerclage wire present within the fracture margin. The femoral stem, acetabular cup, and six cerclage wires are unchanged.

Fig 2 A) Craniocaudal projection radiograph immediately after open reduction and internal fixation ~~demonstrated~~ documenting acceptable reduction but suboptimal screw purchase in the proximal segment. B) Craniocaudal projection radiograph 6 days following fracture repair revealed fixation failure, as evident by gap formation between the plate and greater trochanter (black arrow) and collapse of the fracture site (black arrowhead)

Fig. 3 A) Lateral projection radiograph of the right femur three years prior and B) immediately prior to THR. Note the development of cortical thinning evident by comparing the radiographs.

Fig. 4 Intraoperative photograph of the proximal aspect of the surgical approach, prior to tensioning of the cable cerclage. A positioning pin was threaded into the locking portion of the screw hole (black arrow). A cable wire (white arrow) was passed circumferentially around the proximal femur, threading through the positioning pin, then the pre-placed crimp (grey arrow).

Fig 5. A) Craniocaudal and B) mediolateral projection radiographs immediately following revision with the cable system. Three cerclage cables (black arrows) secured the proximal femoral metaphysis to the plate, which are linked to the plate via positioning pins (white arrows). The THR implants are unchanged.

Fig 6. A) Craniocaudal and B) mediolateral projection radiographs 3 months following revision with the cable system, ~~demonstrating~~ documenting no loss of reduction, stable implants, and bony callus formation at the fracture site.

Fig 7. A) Craniocaudal and B) mediolateral projection radiographs 13 months following revision with the cable system, documenting stable implants, and progressive remodeling at the fracture site.