



Revision of a Press Fit Biological Fixation Stem Fracture in a Dog

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VCOT Open 2019;2:e19–e26.

Abstract

This report describes a clinical case of a press fit biological fixation femoral implant neck fracture (fatigue failure) and its revisions in a dog. A total hip arthroplasty revision was performed. The stem was replaced with a bigger one through a V-shape osteotomy of the proximal–lateral aspect of the femur. Stabilization was accomplished using a locking plate and two over-the-plate cerclage wires. Subsidence of the femoral stem occurred following revision and was revised with a second revision in which a collared stem was used. Two revision surgeries were necessary to have a stable functional prosthesis with successful bone integration at 7 months postoperative reevaluation. Major errors encountered in this case were placement of an undersized stem and an inadequate femoral canal stability/press-fit. Fracture of a BFX femoral stem neck has not been previously reported.

Keywords

- Total Hip Replacement
- arthroplasty
- revision surgery
- dogs
- joint replacement

Introduction

Total hip replacement (THR) is a surgical procedure performed to manage coxofemoral pathology.¹ Total hip replacement eliminates peripheral pain and central sensitization resulting from hip dysplasia.^{2,3} Primary indications for THR include severe coxofemoral osteoarthritis, non-reducible or chronic hip luxations, avascular necrosis of the femoral head, capital physeal fractures, revision of femoral head and neck excision.^{1,4–9} Several cementless and cemented systems are commercially available for use in small animal practice^{1,10–12} with a complication rate ranging from 3.8 to 20%.^{1,10–14} Complications encountered after canine THR include luxation, infection, implant failure, granuloma formation, aseptic loosening, femoral fracture, stem subsidence, sciatic neuropathy, pulmonary embolism, femoral medullary infarction and osteosarcoma.¹

Cementless THR systems have been introduced to avoid cement-related complications, such as aseptic loosening and

irreversible infection.^{15,16} The biological fixation system (BFX) is a cementless hip prosthesis in which the cup and stem are designed to achieve initial press-fit stability and, later on, long-term stability through porous bone ingrowth.¹⁷ This report describes a clinical case of a BFX femoral stem neck fracture (fatigue failure) and its revisions.

Case Report

A 1-year-old female American Staffordshire Terrier weighing 19 kg was referred to our clinic for a non-weight bearing right hindlimb lameness after a fall from a balcony. A non-reducible multifragmentary right femoral head fracture was identified radiographically. A total hip replacement was planned. A 20-mm BFX acetabular cup, number BFX stem and a +3 mm, 12-mm-diameter head (BioMedtrix; Whippany, New Jersey, United States) were implanted. Radiographs performed 2 months after surgery showed stable bony ingrowth (–Fig. 1).

received
September 29, 2018
accepted after revision
February 5, 2019

DOI <https://doi.org/10.1055/s-0039-1683892>.
ISSN 2625-2325.

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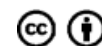




Fig. 1 Preoperative ventrodorsal hip extended, pelvic radiographic view (A) showing an articular non-reducible multifragmentary femoral head fracture of the right femur. Postoperative ventrodorsal hip extended, pelvic radiographic view (B) and mediolateral femoral view (C). A cementless total hip has been implanted. The stem is size number 4, the prosthetic cup is 20-mm with a +3, 12 mm diameter prosthetic head. A ventrodorsal hip extended, pelvic radiographic view acquired 2 months after surgery (D) shows osseointegration of the cup and stem.

Four years after surgery, a right hind limb non-weight-bearing lameness occurred acutely while the dog was running. A fatigue failure at the junction of the stem neck and shaft was seen on radiographs. Implant loosening, bone resorption or fracture of the femur was not observed. Eccentric position of the prosthetic head in the cup suggested severe cup liner wear (►Fig. 2).

The prosthetic head and fractured neck were removed using a craniolateral approach.¹⁸ Radiographic signs of dorsal acetabular rim wearing were noticed after surgery, see-

ingly due to impingement of the prosthetic neck on the lateral aspect of the cup and adjacent bone. One month later, the lameness had not improved and a stem revision surgery was planned. An extended trochanteric osteotomy was performed (►Fig. 3), and the stem was removed. The osteotomized segment was reduced and secured using a six-hole, 139-mm-long, 2.5-mm-thick locking stainless steel plate (V3304 Fixin Intrauma; Rivoli (TO), Italy) placed on the lateral surface of the proximal portion of the femur. Three monocortical titanium alloy 3.0 mm locking screws were

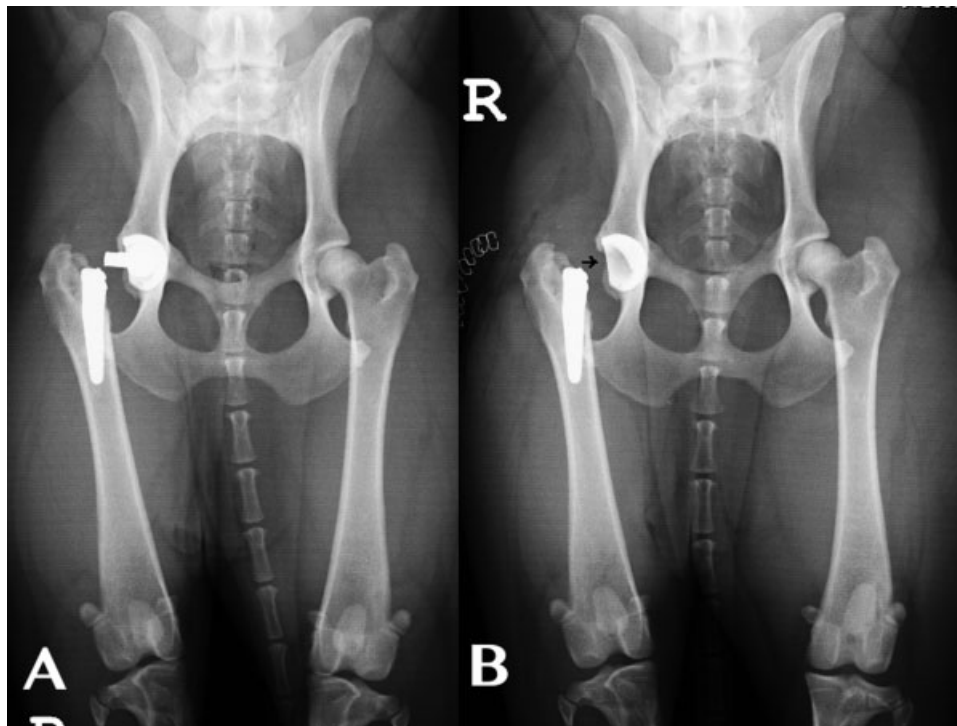


Fig. 2 (A) Ventrodorsal hip extended, pelvic radiographic view showing the fatigue failure of femoral stem 4 years after total hip replacement. (B) Postoperative ventrodorsal view of the pelvis after prosthetic neck and head removal. Bone damage on the dorsal acetabular rim is visible (arrow).

inserted proximally and three bicortical 3.5 mm locking screws were inserted distally. Two 1.25-mm-diameter single-loop cerclage wires (DePuy Synthes; West Chester, Pennsylvania, United States) were applied over the plate to provide additional stability. Polyethylene wear was confirmed intraoperatively and the polyethylene liner was removed. A new 20 mm polyethylene liner with 13 mm internal diameter (ID) to accommodate the femoral head diameter of the larger stem was impacted into place.¹⁹ The femoral canal was broached for the insertion of a new femoral stem using a number 5 broach (BioMedtrix). A number 5 BFX stem (BioMedtrix) was inserted. A 13-mm-diameter +5 mm prosthetic head (BioMedtrix) was impacted on the trunnion.¹⁷ Postoperative radiographs were acquired. Follow-up clinical examination and radiographs of the pelvis were performed at 12 weeks after surgery. The femoral stem had subsided by 4 mm. A weight-bearing lameness was visible. One month later, radiographic re-evaluation demonstrated lack of bone ingrowth and a loose stem (►Fig. 4). A revision surgery was scheduled. The two cerclage wires and the locking bone plate were removed. The femoral stem was loose and manually extracted. The femoral canal was broached using a number 6 and a number 7 broach (BioMedtrix). A number 7 BFX collared stem (BioMedtrix) was inserted. A 13mm + 5 head was applied. Stem alignment was considered adequate on postoperative radiographs. Follow-up clinical examination and radiographs of the pelvis were performed at 8 weeks (►Fig. 5) and at 7 months after the second revision. The dog was pain-free upon palpation or hip manipulation without visible lameness at a walk or trot. The stem was well

osseointegrated, with no measurable subsidence relative to postoperative radiographs.

Discussion

In the short term, the stability of cementless BFX cups and stems relies on press-fit. In the long term, stability is afforded by bone ingrowth.¹⁵ Breakage of the femoral prosthetic component in THR in dogs is rare.²⁰ The original size number 4 stem placed in the dog in this report was made of cobalt chrome (ASTM F75), using investment casting. The dog weight (19 kg) was 40% greater than the maximal recommended weight for that stem size (13.6 kg). At the time of the initial THR surgery performed on this patient, a size chart correlating recommended implant size and patient body weight were not yet available from the manufacturer. However, it should be noted that in the BioMedtrix Universal Hip System the 20 mm cup accepts a 12 mm head, and only the number 4 stem accepts the 12 mm head. Therefore, since a 20 mm cup was placed in this patient, a number 4 stem was necessarily implanted. To insert a number 5 stem, a 22 mm cup that accepts a 14 mm head would need to be used. The choice to place the 20 mm cup and number 4 stem was based on intraoperative decision-making regarding the acetabular dimensions and appropriate prosthetic cup size, and achieving a stable press fit of the number 4 stem. Bony ingrowth occurred uneventfully, demonstrating that femoral stem size and press fit within the femoral canal were adequate. However, chronic loading was the likely cause of fatigue failure of the number 4 stem in this patient, and it should be noted that the number 4 stem has a smaller neck diameter than the

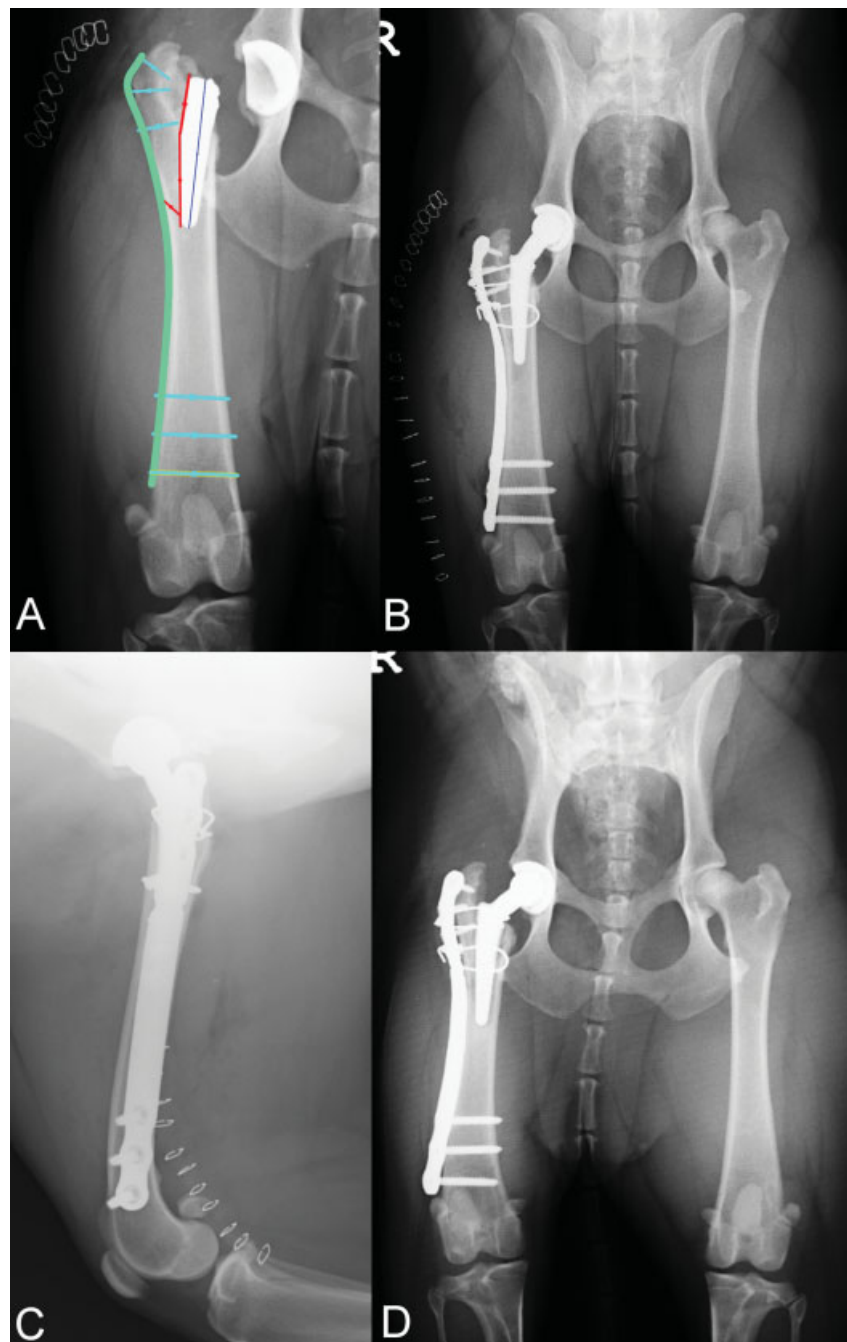


Fig. 3 (A) Preoperative revision planning. The green line represents the plate and pale blue lines the screws. The red lines outline the osteotomy. The blue line measures the stem length. (B) Ventrodorsal hip extended, pelvic radiographic view after prosthesis revision surgery. (C) Postoperative mediolateral view of the right femur. (D) Twelve weeks after surgery, radiographic follow-up shows 4 mm of stem subsidence and a lack of osseointegration, with a radiolucent zone surrounding the stem, and femoral medullary sclerosis distal to the stem tip.

number 5 to 12 stems in the BFX system. The selection of appropriately sized acetabular and femoral components can be challenging in patients that are at the upper or lower limits of the implant size range. Certain acetabular cups are only compatible with certain stems and vice versa. The BFX 20 mm cup is now available with both 12 mm and 13 mm ID. The cup with the 12 mm ID is compatible with the number 4 stem, and the cup with the 13 mm ID is compatible with stem sizes number 5 to 12, thus more flexibility in cup and stem size selection have been incorporated into the BFX system.

Beyond stem size, the stem geometry and material properties are factors in stem breakage. Although the number 5 stem has a larger diameter femoral neck than the number 4 stem, the femoral neck of the number 5 stem is longer. A longer neck increases femoral offset, increasing the load applied to the stem through the femoral head. Prosthetic neck bending stiffness increases with increases in neck diameter to the fourth power, but that stiffness decreases with increases in neck length to the third power.^{21,22} For example, an increase in diameter from 5.5 to 7.5 mm with an increase in neck length from 20 to 24 mm would lead to a

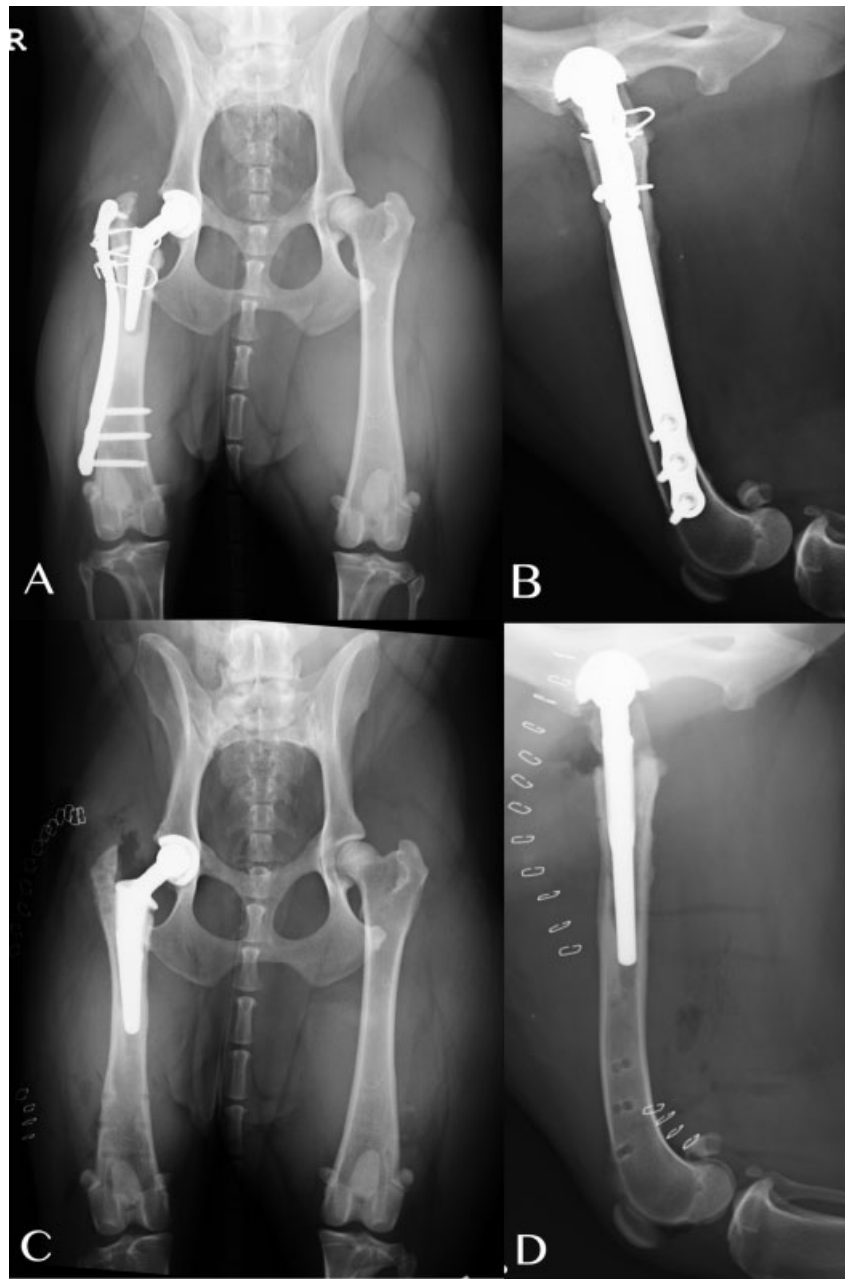


Fig. 4 (A) Ventrodorsal hip extended, pelvic radiographic view acquired 4 months after the revision showing further distal stem subsidence, osteolysis around the stem and lack of osseointegration with femoral medullary sclerosis distal to the stem tip. (B) Mediolateral view of the right femur 4 months after revision surgery. (C) Ventrodorsal hip extended, pelvic radiographic view after second revision surgery. A size number 5 biological fixation (BFX) stem was replaced with a collared size number 7 BFX stem. To prevent varus orientation of the broaches, a 1 mm slice of bone was excised from the medial aspect of the greater trochanter. (D) Postoperative mediolateral view of the right femur after second revision surgery.

combined twofold increase in bending stiffness of the prosthetic neck.

The stem in the current report was made of cobalt chromium alloy. More recently, stems have been three-dimensional printed in titanium alloy (Ti6Al4V). Titanium alloy and cobalt chromium alloys have similar fatigue strength.²³ However, three-dimensional printed implants could conceivably be more prone to breaking because of manufacturing defects and the negative impact of these defects on fatigue life.²⁴ In a recent case series describing custom three-dimensional printed implants used in limb

sparing, two of six implants broke during the first postoperative year.²⁵ Unlike custom three-dimensional printed implants, commercial three-dimensional printed stems undergo a validation process that minimizes the likelihood of manufacturing defects and fatigue failure. In humans, stem fatigue failure (breakage) is reported in ~0.27% of patients.²⁶ Metal fatigue failure has been described to be the most common cause of breakage of prosthetic stems, typically occurring in the middle third of the stem. A correlation between the metal grain size and resistance to fatigue has been reported.²⁶ By comparison in cemented THR,



Fig. 5 Ventrodorsal hip extended, pelvic radiographic view (A) and mediolateral (B) radiographic view acquired 8 weeks after the second revision surgery (implantation of the number 7 stem). The stem is stable and appears well osseointegrated. (C) Ventrodorsal hip extended, pelvic radiographic view 7 months after the second revision surgery. No subsidence has occurred, and the stem appears well osseointegrated. (D) Mediolateral view of the right femur after 7 months from the second revision surgery. Right thigh muscle mass was improved compared with postoperative radiographs.

fracture of cemented stem is usually secondary to the lack of cement in the femoral canal.²⁰

Appropriate prosthesis size is selected preoperatively using digital templating or acetate template overlays applied to radiographs. Calibrated radiographs are taken for correct implant size selection. For the femoral stem selection, the largest implant that fills the confines of the endosteal margins of the metaphysis and diaphysis is selected.¹⁷ Final

implant size is determined during surgery.¹⁷ At the time of initial THR, implants sizes were selected while templating radiographs and confirmed during surgery. The initial number 4 stem was caudally directed and the contact of the stem with the caudal cortex could have interfered with placement a stem with an appropriate size. Radiographic evidence of polyethylene wear was observed at the time of revision. Highly active dogs have an increased cycle frequency and

load, which increase polyethylene wear rates compared with quiet dogs.²⁷

At the time of stem breakage, the revision strategies that were considered included femoral head ostectomy, stem explantation and revision with a larger cementless stem or a cemented stem. A BFX stem implantation was selected based on surgeon's experience with the BFX system and, subjectively, based on sufficient cancellous bone surrounding the stem, considering that the original stem was undersized. An extended trochanteric osteotomy with a V-shape distally was performed. V-type osteotomy provides a bigger surface of bone-on-bone contact between fragments compared with a transverse osteotomy and, as a consequence, might provide greater stability and more rapid healing. This osteotomy also provided access to the ingrowth surfaces of the stable stem, so that they could be broken down with minimal damage to the surrounding cancellous bone. The osteotomy was stabilized, similarly to a type B1 periprosthetic femoral fracture, according to Vancouver classification.²⁸ Monocortical screws were selected for the proximal portion of the plate to avoid interference with the stem. Locking fixation was selected because locking monocortical screws are more stable than non-locking monocortical screws.²⁹ Two cerclage wires were applied to the locking plate to increase stability and to offset the lack of bicortical screws because of the presence of the intramedullary prosthetic stem. The use of a combination of cerclage wires and locking plate has been described in humans and in cats.^{30,31} Cerclage wires increase implant stability.³¹

Minor subsidence < 5 mm may occur in the first post-operative weeks before bone ingrowth takes place and it often does not have clinical consequences.²⁰ One of the causes of major clinical subsidence is poor femur canal preparation³² however, weak cancellous bone and/or an undersized stem can also be contributing factors. The stem selected to fit the femoral canal at the time of the first revision appeared suitable, and a press fit was achieved; however, 12 weeks after revision surgery, signs of severe subsidence were present. Stability provided was not enough to allow osseointegration. The stem had subsided by 4 mm and was loose. Failure of ingrowth may have been due to the lack of compression of the lateral cortical segment onto the stem. Using double loop cerclage wires directly on the bone, in addition to single loop cerclage wires over the locking plate, may have provided more stability and improved press fit.³³ Also, the stem used in the first revision was relatively small (number 5), and the cancellous bone may have been of poor (weak) quality. By comparison, the stem used in the second revision was two sizes larger (number 7) and had a medial collar. The subsidence of the number 5 stem probably compacted the endosteal bone and facilitated the placement of a larger stem at the time of the second revision.

In conclusion, placement of an undersized stem in the first surgery and an inadequate femoral canal stability/press fit following the first revision surgery were errors encountered in this case.

At the time of the first THR, size charts were not available and stem selection was made intraoperatively, based on

press fit. Fatigue stress led to prosthetic stem fracture after 4 years. A more stable femoral window reduction or placement of a larger stem might have avoided subsidence and a second revision surgery.

Author contribution

Massimo Petazzoni and Elena De Giacinto contributed to conception of study, study design, acquisition of data and data analysis and interpretation. Denis Marcellin-Little contributed to study design and data analysis and interpretation. Michael Kowaleski contributed to study design, 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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