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Case Report

Fracture of the Proximal Body of a Modern Cementless Modular Fluted Tapered Stem

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ABSTRACT

Previous reports have described failures of modular fluted tapered femoral stems secondary to fatigue failure at the modular junction. However, the present study is the first reported case of modular fluted tapered femoral component failure involving atraumatic fracture of the proximal body following revision total hip arthroplasty. The failure occurred in a 52-year-old female with a history of postmenopausal osteoporosis on bisphosphonates who sustained an atraumatic fracture of the proximal body of a modular revision femoral stem. In the present case, revision THA utilizing a wider proximal body segment with proximal augmentation using strut allografts for biological and mechanical support provided the patient with a stable construct at 30-month follow-up.

Introduction

The advent of modern modular femoral stem designs has enabled arthroplasty surgeons to achieve robust diaphyseal engagement while simultaneously restoring offset, anteversion, and leg length [1]. In particular, the use of modular fluted tapered (MFT) titanium stems during complex femoral revisions with significant bone loss offers a promising alternative to the use of fully porous-coated femoral stems, which have been associated with an increased risk of intraoperative fracture and stress shielding [2–4]. However, modular femoral stems are susceptible to fatigue failure at the proximal modular junction secondary to cantilever bending forces, particularly in patients with deficient proximal femoral bone stock [5–7].

Risk factors associated with modular femoral stem failure include host factors such as increased body mass index (BMI), increased activity level, and poor proximal femoral support, as well as operative factors including the use of undersized femoral stems [5,8,9]. Nevertheless, the incidence of revision femoral stem fracture remains exceedingly low due to improvements in surgical technique, implant design, and manufacturing processes [10]. Previous studies investigating the failure mechanisms of MFT femoral stems have been limited to fatigue failures and fractures of the modular junction between the proximal body segment and the femoral stem [1,8,11–21]. Efe and Schmitt published a case series of 4 patients with uncemented revision MFT stems, all of whom sustained failures just distal to the neck-stem junction [19]. All 4 patients were found to have proximal component loosening on plain radiographs, with one stem demonstrating arrest lines indicative of fatigue failure on scanning electron microscopy [19].

However, to our knowledge, there has never been a published report describing a proximal body fracture of an uncemented MFT stem. We report the case of a patient with a history of osteoporosis who sustained an atraumatic fracture of the proximal body of the Biomet Arcos revision modular femoral stem (Zimmer Biomet, Warsaw, IN) proximal to the modular junction. This patient was successfully treated with a revision THA utilizing an Arcos high-offset proximal body, Delta Biolox ceramic femoral head (CeramTec, Plochingen, Germany), titanium sleeve, femoral strut grafts, and cerclage cables, demonstrating well-fixed components and a complete absence of hip pain at 30-month follow-up.

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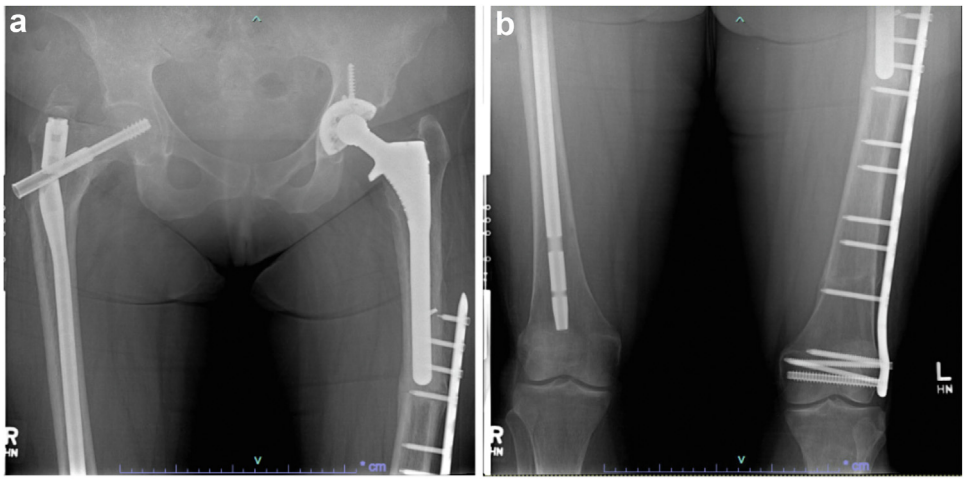

Figure 1. (a) Anteroposterior radiographs of the pelvis and (b) anteroposterior radiographs of the bilateral knees demonstrating a left total hip arthroplasty with a well-fixed cementless femoral stem without evidence of component loosening, osteolysis, or subsidence. With respect to the left lower extremity, there is evidence of open-reduction internal fixation of a prior Vancouver C periprosthetic fracture with hardware failure proximally with screw breakage and backing out of the plate at the distal aspect of the stem. Distally, there is evidence of a well-healed distal femur fracture of the left lower extremity.

The patient was informed that data concerning the case would be submitted for publication, and written informed consent was obtained for publication of this case report.

Case history

A 27-year-old woman underwent uncomplicated primary THA for an atraumatic left femoral neck fracture. She was subsequently diagnosed with severe osteoporosis (T-score −3.2) and received bisphosphonate therapy for 8 years, as well as injectable teriparatide therapy for 2 years, with significant improvement in her bone mineral density scores (repeat T-score −1.4). Unfortunately, she subsequently sustained an atraumatic left Vancouver C periprosthetic femur fracture at 9 years following primary THA, which was attributed to chronic bisphosphonate use. This fracture was managed with open reduction and internal fixation (ORIF) at an outside institution using a distal femur plate without locking screws and retention of the primary THA component (Fig. 1). This construct ultimately failed, requiring revision ORIF (approximately 13 years following initial ORIF for the pathologic left Vancouver C periprosthetic femur fracture) with removal of the prior plate and placement of a new locking plate construct with cerclage wires spanning the proximal femur (Fig. 2).

The patient first presented to our clinic with persistent, significant pain approximately 4 months following the revision ORIF. Radiographs demonstrated well-fixed acetabular and femoral components but persistent nonunion of the prior transverse Vancouver C periprosthetic femur fracture with varus and apex-anterior angulation. Preoperative workup revealed a low suspicion of infection with an erythrocyte sedimentation rate of 5 mm/h and C-reactive protein value of 13.9 mg/L. Given the patient's

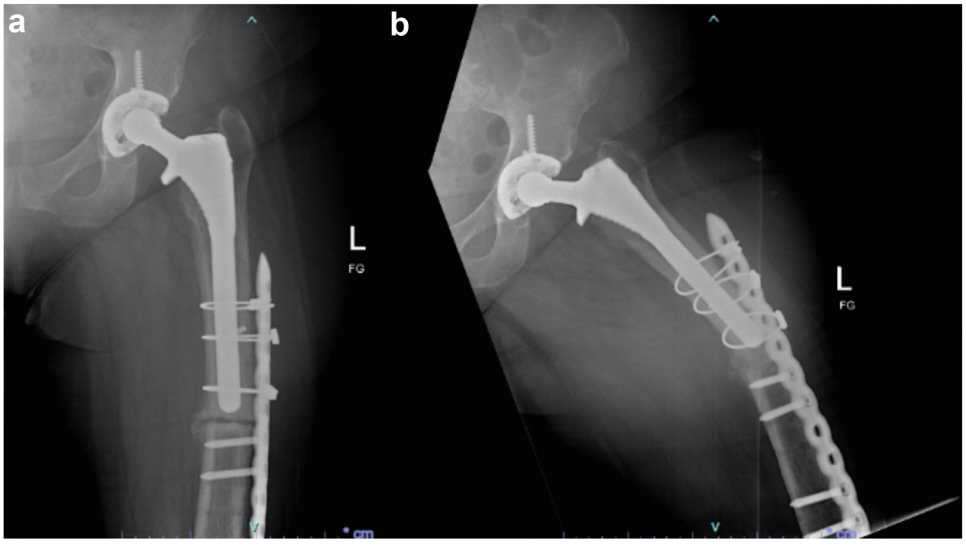

Figure 2. (a) Anteroposterior and (b) frog-leg lateral radiographs of the left hip demonstrating interval revision open-reduction internal fixation with evidence of an impending apex anterior sagittal malunion of the Vancouver C periprosthetic femur fracture. There is evidence of callus formation; however, there is no evidence of bridging mature bone indicative of a nonunion. Notably, proximal fixation was achieved with cerclage wire fixation without any screws in the proximal fragment, likely contributing to the impending malunion.

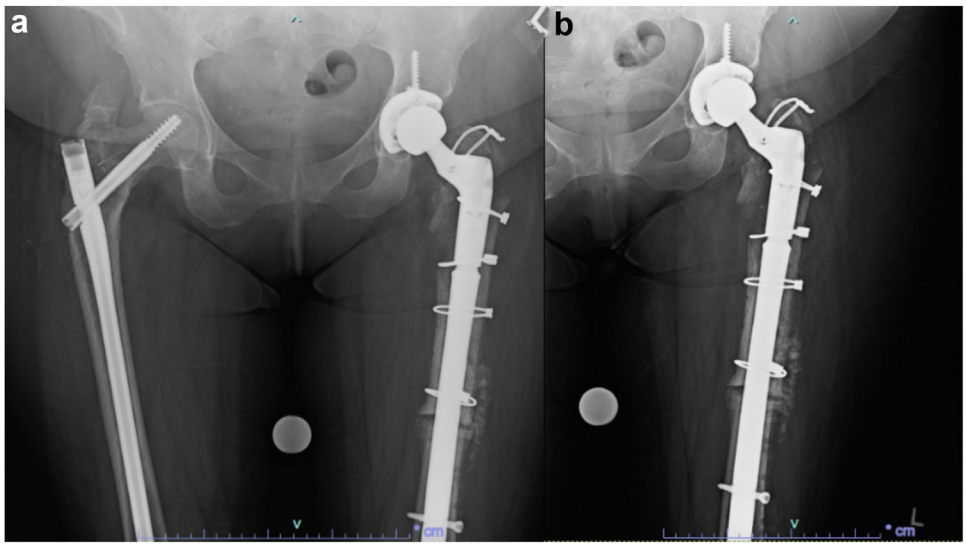

Figure 3. (a) Anteroposterior radiographs of the pelvis and (b) anteroposterior radiographs of the left hip demonstrating interval revision total hip arthroplasty with appropriately positioned components and evidence of a trochanteric osteotomy. Femoral reconstruction was performed using an Arcos interlocking revision fully porous-coated 17 × 30-mm stem with a 70A high-offset conical body, Delta Biolox ceramic femoral head, as well as cerclage cables and wires for proximal reinforcement.

persistent, progressive pain despite 2 prior attempts at ORIF, the patient was recommended for revision left THA.

Revision left THA was performed, and tissue from the nonunion site was sent for frozen section intraoperatively, revealing no evidence of acute inflammation. Stem extraction was performed with a Wagner osteotomy, flexible osteotomes, and burr. A vitamin E cross-linked polyethylene liner was scored and cemented into the well-fixed acetabular component. Femoral reconstruction was performed using a 17 × 300 mm Arcos interlocking distal stem with extensive porous plasma titanium distal coating (Zimmer Biomet, Warsaw, IN), 3 distal interlocking screws, size 70A high-offset proximal body, and 32 mm, −3 mm Delta Biolox ceramic femoral head (CeramTec, Plochingen, Germany; Fig. 3). Bone harvested from the reamings and the resection was morselized, mixed with 10 mL of Accell Evo3 DBX (SeaSpine, Carlsbad, CA), and placed within the nonunion site.

Postoperatively, the patient's nonunion was managed with a bone stimulator, nasal calcitonin, and abaloparatide. The patient

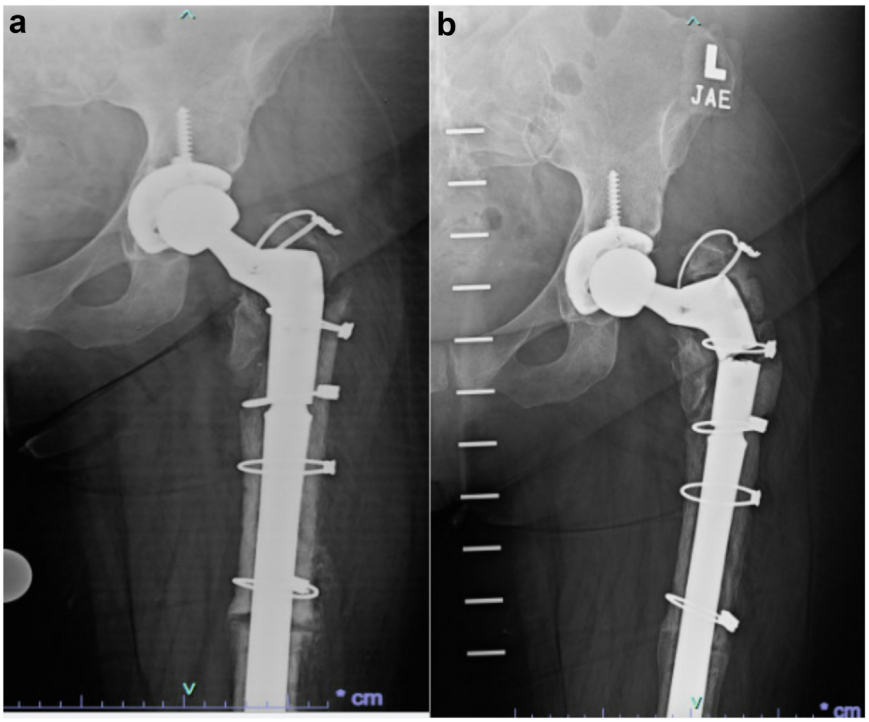

Figure 4. (a) Anteroposterior radiograph of the pelvis at 3 months postoperatively following revision total hip arthroplasty with Arcos revision femoral stem demonstrating incomplete healing of prior osteotomies without interval hardware complication. (b) Anteroposterior radiograph of the pelvis at 3 years postoperatively demonstrating fracture of the proximal body of the modular stem, above the level of the taper.

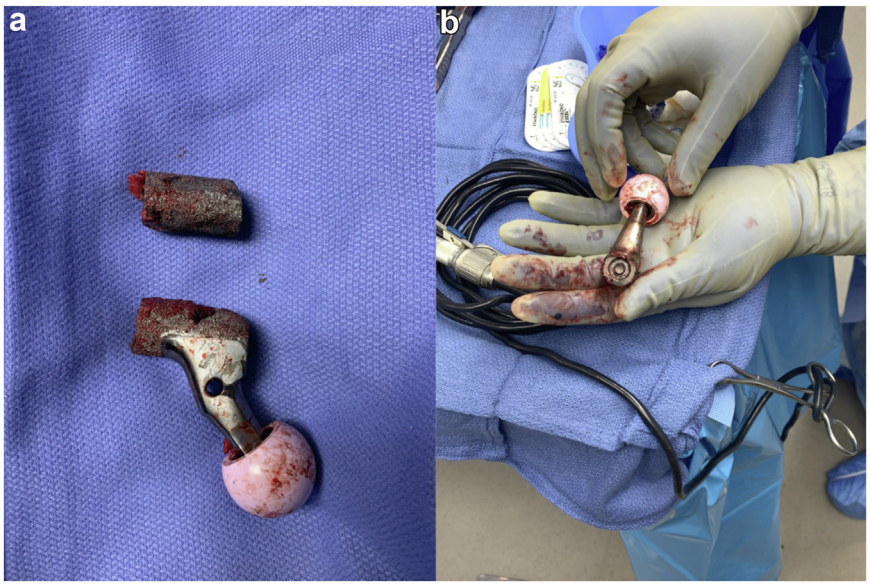

Figure 5. (a) Intraoperative photograph demonstrating proximal body fracture of the Arcos revision femoral stem following explantation, (b) without evidence of corrosion at the head-stem trunnion.

was able to ambulate approximately 1600 m without pain or assistive devices at 3-year follow-up. Unfortunately, approximately 3 years following the revision left THA, the patient represented with acute, atraumatic left hip pain after she bent over and felt a popping sensation in the left hip. Radiographs demonstrated a fracture involving the proximal body of the modular stem above the taper (Fig. 4). However, the locking stem appeared well-fixed. The patient was admitted overnight for urgent revision surgery.

Revision THA was undertaken, again using a Wagner osteotomy for exposure and removal of the fractured proximal body segment (Fig. 5). The trunnion was meticulously examined and found to be without gross damage. A new larger Arcos size 60D high-offset proximal body was then placed. The femoral head was impacted with a new 32 mm, +3 mm Delta Biolox ceramic femoral head with a titanium sleeve. Two strut allografts were placed with 20 ml of DBX putty (DePuy Synthes, Warsaw, IN) and 4 cerclage cables (Fig. 6).

Postoperatively, the patient's osteoporosis was managed with romosozumab beginning approximately 10 months following the re-revision THA. The patient had an uneventful postoperative course and was ambulating pain free with a walker at 3 months postoperatively, with cane assistance at 4 months postoperatively, and without assistive devices at the final 30-month follow-up. In addition, serial radiographs obtained between 6 weeks and 30 months postoperatively demonstrated well-fixed components with appropriate consolidation of the femoral strut grafts (Fig. 7).

Discussion

Modular femoral stem fracture is a rare complication following revision THA, occurring primarily in patients with high BMI, increased activity level, poor proximal bone stock, and undersized femoral stems [22]. The present case report describes a 52-year-old female with a history of osteoporosis (T-score −3.2) and an elevated BMI (33.7 kg/m^2) who sustained an atraumatic fracture of the proximal body of an MFT femoral stem proximal to the modular junction. This patient was successfully treated with a revision THA utilizing a larger-diameter proximal body with femoral strut grafts. Prior studies investigating the failure mechanisms of MFT femoral stems have been limited to reports of fatigue failures and fractures at the modular junction [1,8,11–21]. However, the present study is

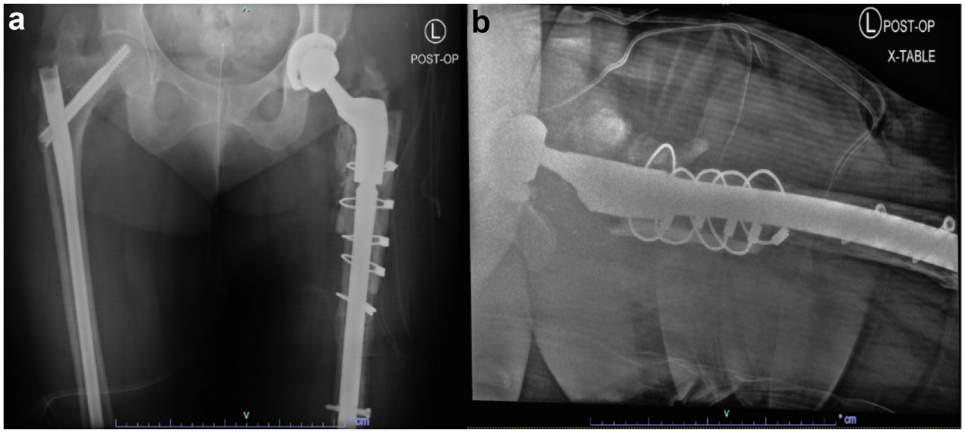

Figure 6. (a) Anteroposterior radiographs of the pelvis and (b) cross-table lateral radiographs of the left hip demonstrating interval revision total hip arthroplasty with exchange to a shorter, wider, Arcos size-60D high-offset proximal body, Delta Biolox ceramic femoral head with titanium sleeve, and reinforcement using medial and lateral strut allografts held in place by cerclage cables to augment construct stability.

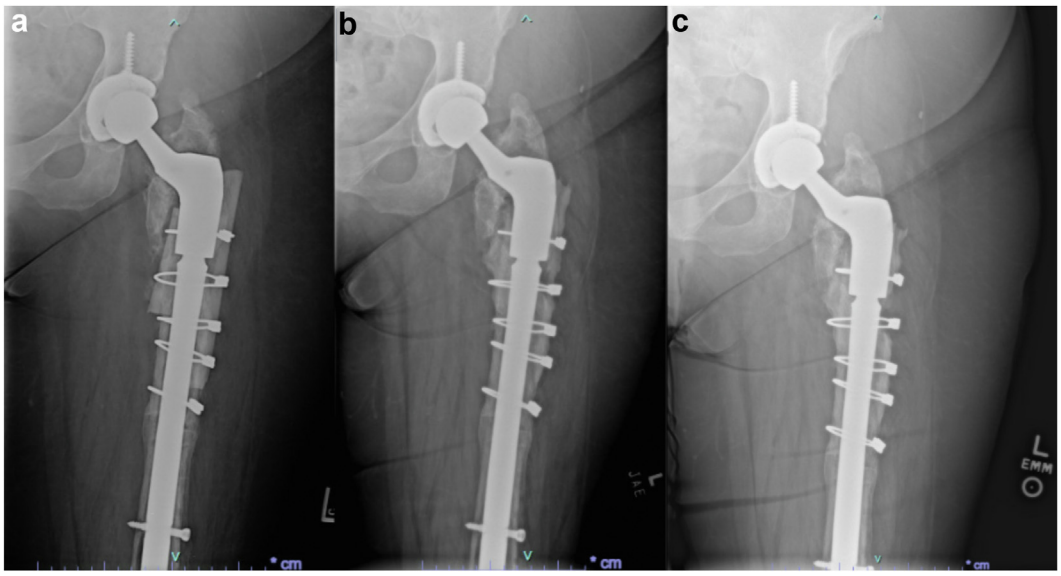

Figure 7. Anteroposterior radiographs of the left hip at (a) 3 months, (b) 22 months, and (c) 30 months postoperatively following revision total hip arthroplasty for fracture of the proximal body of the modular stem demonstrating well-fixed femoral components with interval callus formation and improved bone density.

the first to our knowledge to describe failure of an uncemented MFT femoral stem secondary to fracture through the proximal body itself.

The utilization of cementless MFT revision stems to address deficient femoral bone stock during revision THA has continued to increase in recent years, exhibiting excellent survivorship at midterm follow-up [3,14,23]. As demonstrated in the present case, one significant benefit of the modular stem design involves the ability to exchange the modular proximal body without the need for explantation and revision of the entire femoral component. While modularity enables intraoperative adjustment of leg length, femoral version, and offset, modular femoral stems have been associated with the potential for modular junction failure and stem fracture [8,11–21,24,25].

The risk of fatigue fracture is further increased with patient-specific risk factors, such as elevated BMI, high activity level, deficient proximal bone stock, and undersized stem diameter [18,26,27]. In the present case, our patient's risk of fatigue fracture was likely elevated due to underlying metabolic bone disease, for which she underwent prior prophylactic fixation of the contralateral (right) femur with a cephalomedullary nail in 2009. This cephalomedullary nail subsequently fractured, requiring revision fixation in 2018 (Fig. 1a). Prior to presentation at our institution, the patient underwent extensive workup for metabolic bone disease by multiple physicians and endocrinologists; however, no specific reversible etiology was ever elucidated. A course of bone stimulator therapy, nasal calcitonin, and injective abaloparatide was initiated to promote increased bone density and facilitate healing, resulting in complete radiographic union of the prior left hip Vancouver C periprosthetic fracture with bridging callus formation just prior to failure of the left modular femoral stem at the proximal body above the level of the taper. In the absence of a significant traumatic event, several factors likely contributed to the proximal body fracture seen in our patient, including an elevated BMI (33.7 kg/m^2) and poor proximal bone stock secondary to osteoporosis. In addition, genetic contributions to peak bone mass have previously been well described in the literature. Rubin et al. examined a cohort of 667 healthy, unrelated Caucasian women and performed genotyping of the vitamin D receptor locus at 3 polymorphic sites, demonstrating that the vitamin D receptor locus contributed approximately 17%-21% of the variability in peak hip and spine bone mineral density in their cohort [28]. Although the patient in the present study never underwent formal genetics evaluation, an unidentified underlying genetic association may have contributed to her poor bone mineral density.

Given the severe proximal bone loss encountered, we chose to augment our construct with medial and lateral strut allografts to provide biological and mechanical support to the femur and implant taper junction. These medial and lateral strut grafts were augmented with demineralized bone matrix to facilitate bone incorporation. Furthermore, a wider proximal body segment was utilized to increase structural resistance to bending forces. Finally, the proximal native bone and strut allografts appeared well fixed with bony incorporation at 30-month follow-up.

Summary

Modular femoral stem fracture is a rare postoperative complication following total hip arthroplasty, typically occurring due to fatigue failure at the modular stem junction. To date, no prior report of fracture through the proximal body of an MFT femoral stem has been documented in the literature. In the present case, revision THA utilizing a wider proximal body segment with proximal augmentation using strut allografts for biological and mechanical support provided the patient with a stable construct at 30-month follow-up.

Acknowledgments

The patient was informed that data concerning the case would be submitted for publication, and she provided consent.

Conflicts of interest

NDH receives royalties from Corin U.S.A.; is a paid consultant for Intellijoint Surgical, MicroPort Orthopedics, Corin U.S.A., and Zimmer; has stocks or stock options with Intellijoint Surgical; and is a board member at American Academy of Orthopaedic Surgeons, American Joint Replacement Registry, and the American

Association of Hip and Knee Surgeons (AAHKS). DAO receives royalties from Lima Corporate. All other authors declare no conflicts to disclose.

For full disclosure statements, refer to https://doi.org/10.1016/j.artd.2024.101472.

Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

CRediT authorship contribution statement

Brian C. Chung: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Pranit Kumaran:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Nathanael D. Heckmann:** Writing – review & editing, Supervision, Resources, Conceptualization. **Daniel A. Oakes:** Writing – review & editing, Supervision, Resources.

References

[1] Duncan ST, Hayes CB, Nunley RM. Fracture at the modular junction of a cementless revision hip system: a case report. JBJS Case Connect 2016;6:e48.
[2] Moreland JR, Moreno MA. Cementless femoral revision arthroplasty of the hip: minimum 5 years followup. Clin Orthop Relat Res 2001:194–201.
[3] Gutiérrez del Alamo J, Garcia-Cimbrelo E, Castellanos V, Gil-Garay E. Radiographic bone regeneration and clinical outcome with the wagner SL revision stem: a 5-year to 12-year follow-up study. J Arthroplasty 2007;22:515–24.
[4] Boisgard S, Moreau PE, Tixier H, Levai JP. Bone reconstruction, leg length discrepancy, and dislocation rate in 52 Wagner revision total hip arthroplasties at 44-month follow-up. Rev Chir Orthop Reparatrice Appar Mot 2001;87:147–54.
[5] Wroblewski BM. Fractured stem in total hip replacement. A clinical review of 120 cases. Acta Orthop Scand 1982;53:279–84.
[6] Charnley J. Fracture of femoral prostheses in total hip replacement. A clinical study. Clin Orthop Relat Res 1975:105–20.
[7] Matar HE, Selvaratnam V, Board TN, Purbach B, Porter ML, Kay PR, et al. Fractured femoral stems in primary and revision hip arthroplasties revisited: wrightington experience. J Arthroplasty 2020;35:1344–50.
[8] Lakstein D, Eliaz N, Levi O, Backstein D, Kosashvili Y, Safir O, et al. Fracture of cementless femoral stems at the mid-stem junction in modular revision hip arthroplasty systems. J Bone Joint Surg Am 2011;93:57–65.
[9] Bolland BJRF, Wilson MJ, Howell JR, Hubble MJW, Timperley AJ, Gie GA. An analysis of reported cases of fracture of the Universal exeter femoral stem prosthesis. J Arthroplasty 2017;32:1318–22.
[10] Heck DA, Partridge CM, Reuben JD, Lanzer WL, Lewis CG, Keating EM. Prosthetic component failures in hip arthroplasty surgery. J Arthroplasty 1995;10:575–80.
[11] Harmer JR, Hadley ML, Trousdale RT. Modular proximal body exchange for Re-revision total hip arthroplasty: rarely utilized and moderately successful. J Arthroplasty 2023;38:S229–234.e1.
[12] McAlister IP, Abdel MP. Elevated serum titanium level as a marker for failure in a titanium modular fluted tapered stem. Orthopedics 2016;39:e768–70.
[13] Park C-W, Lee J-H, Shin SS, Moon Y-W, Lim S-J, Park Y-S. Long-term outcomes of revision total hip arthroplasty using a tapered and fluted modular stem: a mean follow-up of 16 years. J Arthroplasty 2022;37:2420–6.
[14] Abdel MP, Cottino U, Larson DR, Hanssen AD, Lewallen DG, Berry DJ. Modular fluted tapered stems in aseptic revision total hip arthroplasty. J Bone Joint Surg Am 2017;99:873.
[15] Van Houwelingen AP, Duncan CP, Masri BA, Greidanus NV, Garbuz DS. High survival of modular tapered stems for proximal femoral bone defects at 5 to 10 years followup. Clin Orthop Relat Res 2013;471:454–62.
[16] Butler Ransohoff C, Wanner R, Solinger T, Gautier E, Eijer H, Wahl P. The different failure modes of the connecting elements of the modular hip arthroplasty revision stem Revitan. J Mech Behav Biomed Mater 2021;123:104778.
[17] Rodriguez JA, Deshmukh AJ, Robinson J, Cornell CN, Rasquinha VJ, Ranawat AS, et al. Reproducible fixation with a tapered, fluted, modular, titanium stem in revision hip arthroplasty at 8-15 years follow-up. J Arthroplasty 2014;29:214–8.
[18] Konan S, Garbuz DS, Masri BA, Duncan CP. Modular tapered titanium stems in revision arthroplasty of the hip. Bone Joint J 2016;98-B(1 Suppl A):50–3. https://doi.org/10.1302/0301-620X.98B1.36442.
[19] Efe T, Schmitt J. Analyses of prosthesis stem failures in noncemented modular hip revision prostheses. J Arthroplasty 2011;26:665.e7.
[20] Norman P, Iyengar S, Svensson I, Flivik G. Fatigue fracture in dual modular revision total hip arthroplasty stems: failure analysis and computed tomography diagnostics in two cases. J Arthroplasty 2014;29:850–5.
[21] Nasr PJ, Keene GS. Revision of a fractured uncemented revision stem using a custom designed punch and retrograde through-knee approach. Case Rep Orthop 2015;2015:485729.
[22] Rueckl K, Sculco PK, Berliner J, Cross MB, Koch C, Boettner F. Fracture risk of tapered modular revision stems: a failure analysis. Arthroplast Today 2018;4:300–5.
[23] Hannon CP, Sheehan KP, Duong SQ, Yuan BJ, Lewallen DG, Berry DJ, et al. Modular fluted tapered stems for periprosthetic femoral fractures: excellent results in 171 cases. J Bone Joint Surg Am 2022;104:1188–96.
[24] Barrack RL. Orthopaedic crossfire—stem modularity is unnecessary in revision total hip arthroplasty: in the affirmative. J Arthroplasty 2003;18:98–100.
[25] Garbuz DS, Toms A, Masri BA, Duncan CP. Improved outcome in femoral revision arthroplasty with tapered fluted modular titanium stems. Clin Orthop Relat Res 2006;453:199–202.
[26] Busch CA, Charles MN, Haydon CM, Bourne RB, Rorabeck CH, Macdonald SJ, et al. Fractures of distally-fixed femoral stems after revision arthroplasty. J Bone Joint Surg Br 2005;87:1333–6.
[27] Woolson ST, Milbauer JP, Bobyn JD, Yue S, Maloney WJ. Fatigue fracture of a forged cobalt-chromium-molybdenum femoral component inserted with cement. A report of ten cases. J Bone Joint Surg Am 1997;79:1842–8.
[28] Rubin LA, Hawker GA, Peltekova VD, Fielding LJ, Ridout R, Cole DE. Determinants of peak bone mass: clinical and genetic analyses in a young female Canadian cohort. J Bone Miner Res 1999;14:633–43.