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Case Report

Mechanical insufficiency fractures of modular femoral stems in hip arthroplasty: a case series of three patients

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Abstract

Hip arthroplasty (HA) is a widely accepted treatment method for various hip conditions that significantly reduces pain and improves function. Despite advances in surgical techniques, some patients experience complications that may require revision surgery. Modular femoral stems are widely used in HA because of their advantageous features, such as the ability to adjust femoral offset, leg length, and anteversion. However, mechanical failure can occur at the modular junction. Although rare, this is a serious complication. This study presents three patients who had previously undergone HA and subsequently developed failure at the modular femoral stem junction.

Keywords: Femoral stem fracture, modular femoral stem, implant failure, arthroplasty, total hip arthroplasty, hemiarthroplasty

Introduction

Total hip arthroplasty (THA) and bipolar hemiarthroplasty (BHA) are surgical procedures commonly used to treat degenerative joint diseases, such as osteoarthritis, and other conditions affecting the hip joint like fractures [1, 2]. Arthroplasty has become increasingly common in recent years due to an increase in life expectancy [2]. It is considered the gold standard treatment for end-stage hip osteoarthritis because of its ability to relieve pain, improve mobility, and enhance quality of life [1, 2]. However, the rising frequency of primary arthroplasty has led to a parallel increase in arthroplasty revision rates [2]. Femoral stem fractures account for approximately 1% of revisions after primary THA [3]. The prevalence after revision THA can be even higher and can account for 2-3% of subsequent revisions [3]. While mechanical failure of the femoral component after THA is uncommon, femoral stem fractures have been previously described in the literature [4].

The advent of modular implants in hip revision surgery has provided significant advantages related to the independent preparation of the metaphysis and diaphysis [5]. Modularity offers the ability to adjust and restore joint kinematics—including leg length, version, and offset—independent of the exact position of the distal stem [4]. Fractures are most frequently observed at the junction between the two parts of the modular stem (Figure 1) [5, 6]. Factors that increase susceptibility to this type of stem failure include excessive patient weight, high levels of physical activity, inadequate bone support, incorrect stem positioning or loosening, the presence of stress concentrators, and a reduced cross-sectional area within the stem [4]. This study presents three patients who had previously undergone HA and subsequently developed failure at the modular femoral stem junction.

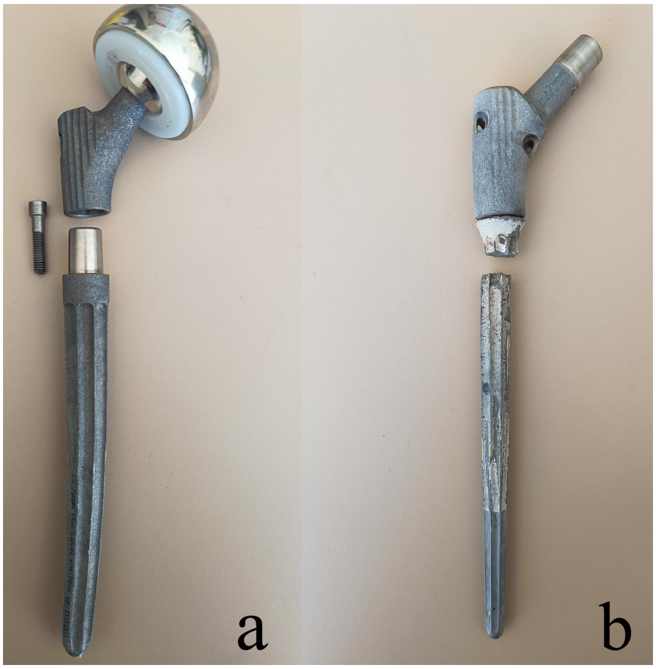

Figure 1. a) View of the neck, stem, and connecting apparatus that comprise the modular femoral stem. **b)** Image of the modular stem fractured near the neck-stem junction.

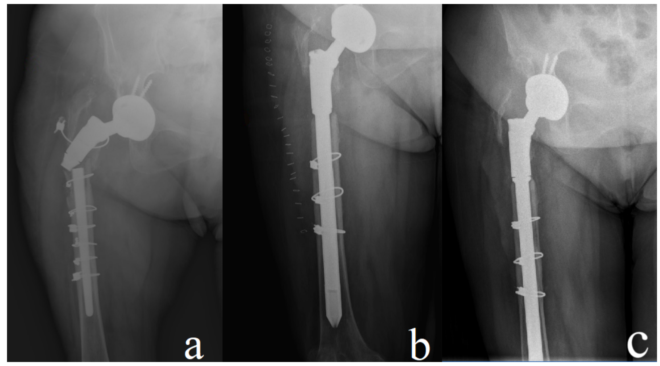

Figure 2. a) Radiograph of a 56-year-old female patient with a fractured modular femoral stem. **b, c)** Postoperative radiograph showing the newly implanted modular femoral stem after removal of the fractured stem via longitudinal femoral osteotomy, and the follow-up image at one-year.

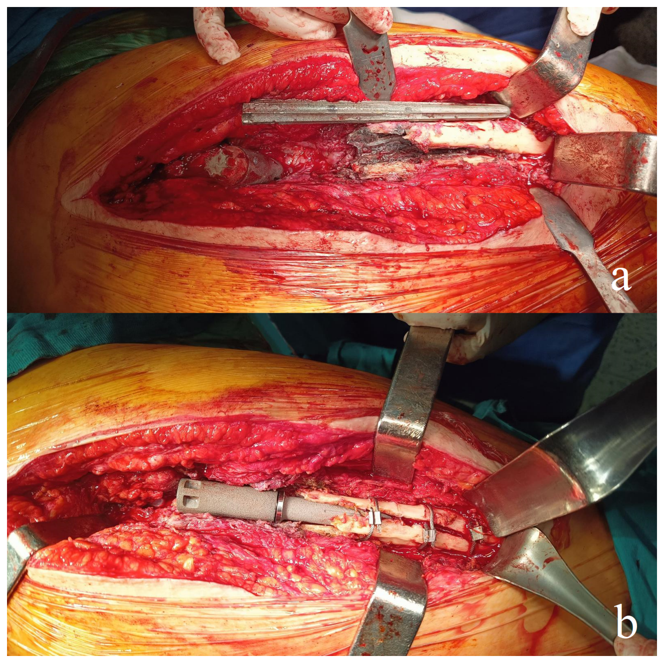

Figure 3. a) Intraoperative photograph demonstrating the removal of the fractured modular femoral stem via a controlled longitudinal osteotomy of the femoral cortex; an extensive bone defect in the proximal femur and associated metallosis are also visible. **b)** Postoperative radiograph showing the newly implanted modular femoral stem, with the osteotomy site secured using cerclage wires.

Case reports

Case 1: A 56-year-old female patient presented with right hip pain following a fall while rising from a chair. Initial radiographs revealed a fracture in the modular femoral stem of her right THA. The patient's surgical history included a primary right THA 15 years prior, followed by the placement of an antibiotic spacer due to a periprosthetic infection, and a subsequent revision surgery using a modular femoral stem. Notably, two years prior to her current presentation, she had undergone a second revision surgery due to a fracture at the same modular neck-stem junction.

During the revision surgery, the fractured portion of the modular femoral stem was removed via a longitudinal femoral cortical osteotomy. Subsequently, the osteotomy site was stabilized using cerclage wires. The acetabular component was not revised as it was found to be stable. The hip was reduced with appropriate anteversion (Figures 2 and 3). The patient was mobilized with partial weight-bearing on the fourth postoperative day. Once adequate union was confirmed on radiographs at the 8-week mark, full weight-bearing was permitted. At the one-year follow-up, radiographs demonstrated that the arthroplasty was stable; the patient was able to walk short distances unassisted and longer distances with support.

Case 2: A 62-year-old female patient presented with sudden pain in her right hip while walking. Initial radiographs revealed a fracture in the modular femoral stem of her THA. The patient's surgical history included a revision THA performed 4 years prior, followed by implant removal and placement of an antibiotic spacer 2 years prior due to a periprosthetic infection. Six months after the spacer placement, she underwent reconstruction using

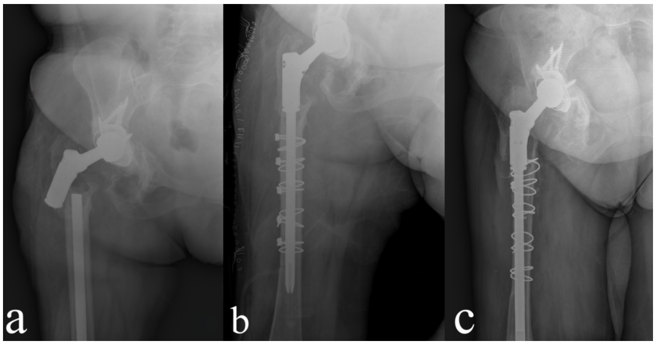

Figure 4. a) Radiograph demonstrating a fracture of the modular femoral stem at the neck-stem junction in a 62-year-old female patient with a prior total hip arthroplasty. **b, c)** Postoperative radiograph showing the newly implanted modular femoral stem after removal of the fractured stem via longitudinal femoral osteotomy, and the follow-up image at one year.

a cage-type acetabular component and a modular femoral stem.

During the revision surgery, the acetabular component was found to be stable and intact. The fractured portion of the modular femoral stem was removed via a longitudinal femoral cortical osteotomy, and a new, appropriately sized modular femoral stem was implanted. Subsequently, allograft bone was placed into the bone defect between the host femur and the new stem, and the osteotomy site was stabilized using cerclage wires (Figure 4). The patient was mobilized with partial weight-bearing on the second postoperative day. Following radiographic confirmation of adequate union at the 6-week mark, the patient was permitted full weight-bearing. At the one-year follow-up, radiographs demonstrated that the arthroplasty was stable, and the patient was able to walk unassisted.

Case 3: A 74-year-old female patient presented to the emergency department with sudden pain in her right hip following a fall from a standing height. Initial radiographs revealed a fracture in the modular femoral stem of her BHA.

The patient's surgical history revealed that she had undergone a right hip BHA two years prior following a fall. During the revision surgery, the fractured portion of the modular femoral stem was removed via a longitudinal femoral cortical osteotomy, and a new modular femoral stem was implanted. Subsequently, the osteotomy site was stabilized using cerclage wires (Figure 5). Postoperatively, the patient was mobilized with partial weight-bearing on the first day. Following radiographic confirmation of adequate union at the 8-week mark, the patient was permitted full weight-bearing. At the one-year follow-up, radiographs demonstrated that the arthroplasty was stable, and the patient was able to walk unassisted.

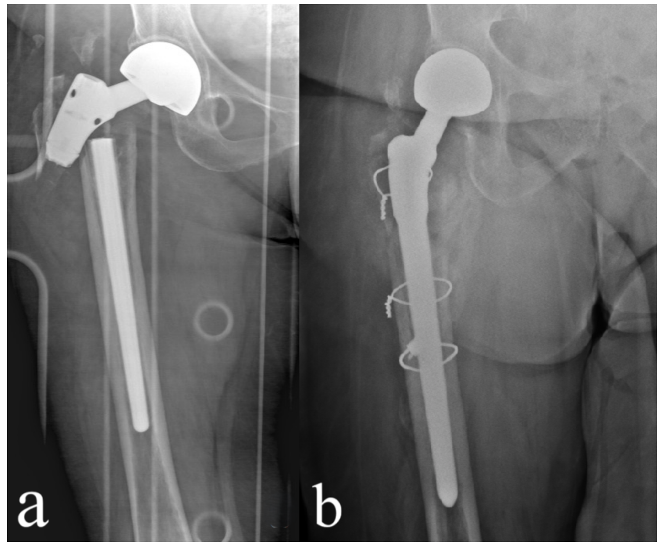

Figure 5. a) Radiograph demonstrating a fracture of the modular femoral stem at the neck-stem junction in a 74-year-old female patient with a prior bipolar hemiarthroplasty. **b)** One-year postoperative radiograph showing the newly implanted modular femoral stem after removal of the fractured stem via longitudinal femoral osteotomy.

Discussion

The use of modular femoral stems has become popular in revision HA and in the reconstruction of bone defects following tumor resection [7]. A key advantage of modularity is the ability to reconstruct patient biomechanics, specifically femoral head offset and leg length [7]. Modularity in both THA and BHA allows for optimal restoration of prosthetic geometry, leg length, offset and anteversion [8].

Mechanical failure in HA is rare and primarily affects the stem and neck, followed by the cup and inner components [6]. Stem fractures represent one form of failure in femoral prostheses [9]. Fractures at the titanium modular neck-stem junction are considered a significant complication that ultimately leads to implant failure [8]. The underlying causes of mechanical failure are largely attributed to friction, cracking, and galvanic corrosion, which loosen the modular connection and precipitate fracture [8]. Corrosion and friction occur at both the head-neck and neck-modular stem connections, increasing in severity with the duration of implant use [8]. Due to the elongation of the lever arm and the resulting increase in mechanical stress, failure most commonly occurs at the neck-stem connection [8]. Additionally, friction and corrosion produce particulate debris and ionic products that trigger the release of inflammatory mediators, further contributing to implant fracture [8].

Due to the differential mechanical loads applied to the modular neck, fatigue fractures most frequently initiate in the anterolateral part of the conical connection in titanium necks [8]. While compressive forces dominate the proximal connection, tensile forces act on the lateral part of the taper, and compressive forces act on the medial distal end [8]. This mechanical discrepancy arises from the moment of force generated by the femoral neck length and the patient's body weight [8, 10].

Both implant-related and patient-related risk factors for modular stem fractures have been established [6, 11, 12]. The primary implant-related factors include a long varus neck, excessive neck anteversion or retroversion, and large-diameter metal-on-metal connections, while patient-related factors primarily involve obesity and high levels of physical activity [8, 11, 12]. Notably, no significant correlation has been observed between implant failure and age, physical load, energy level, or the time elapsed between primary implantation and failure [6]. Although no direct correlation with body mass index was statistically significant in some studies, most affected patients were classified as having class I obesity [6]. Consistent with these observations, Sulje et al. [13] emphasized that increased body mass index, high physical activity, varus stem orientation, an undersized femoral component, and poor proximal bone support resulting from absence of the calcar are principal contributors to this complication, noting that insufficient osseous support markedly elevates stress at the neck-stem junction [12, 14]. In a recent review of Zimmer modular revision stem fractures, Aldowekat et al. likewise identified advanced age (over 65 years), high BMI, and compromised proximal bone stock as patient-related factors, whereas shorter stems (<200 mm), smaller stem diameter (<20 mm), and extended-offset designs constituted the principal implant-related factors; they further underscored that, because the bending strength of a cylindrical stem is proportional to the fourth power of its diameter, even small reductions in diameter substantially decrease its resistance to bending [15].

While modularity allows adaptation to diverse intraoperative scenarios, it carries inherent risks of fracture and corrosion at metallic connections [11]. To mitigate this, specific milling techniques with grit-blasting have been developed to harden taper connections [11]. Furthermore, modern models often incorporate surface coatings on the proximal segment to reduce stress-shielding and prevent mechanical stress peaks at the proximal-distal junction [11]. In a systematic review of 24 modular revision implant fractures, Fink [12] identified a consistent association between distal osseointegration and a lack of proximal bone support; he suggested utilizing the longest possible proximal components to shift the connection into healthy bone.

Removal of a well-fixed distal stem fragment during revision surgery represents a considerable technical challenge, and several extraction techniques have been described. Sulje et al. removed the firmly fixed distal fragment through a longitudinal osteotomy of the anterior femoral cortex extended distally for approximately 15 cm, followed by a transverse osteotomy just below the stem tip to provide sufficient space for extraction [13]. Aldowekat et al. used a diamond-tip drill to create a hole in the stem taper that allowed retrograde hammering of the well-fixed distal component, thereby minimizing further femoral bone loss [15]. Arafah et al. reported the use of an intramedullary trephine reamer under fluoroscopic guidance to disengage a well-fixed distal fragment while preserving the integrity of the femoral cortex, although they cautioned that this approach carries the risks of thermal necrosis and iatrogenic cortical perforation [16]. In all three cases in our study, we performed a longitudinal controlled osteotomy in the femoral cortex to remove the fractured fragment, and then fixed it again with cerclage wires.

In the cases we presented, similar to Fink's [12] view, the proximal modular portions of the fractured stems lacked bone support and osseointegration. Furthermore, due to patient-related factors, most of the cases had undergone repeated surgeries, increasing the risk of implant failure due to poor bone quality [14]. In high-risk patients with poor proximal bone stock, the use of a monoblock, non-modular femoral stem has been suggested as a safer alternative to reduce the risk of this complication [15]. On the other hand, it is anticipated that in the future, implant designs for such failures will further improve, and implant components will become stronger and more durable.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by TÖ, AEG, and AK. The first draft of the manuscript was written by TÖ, AEG, and AK, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Statements and declarations

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical statement

The authors confirm that this case report was conducted in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki and its later amendments. Written informed consent was obtained from the patient for the publication of this case report and the accompanying images.

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