RESEARCH ARTICLE

Cantilever Failure of Modular Uncemented Femoral Revision Stem in Patients with Poor Proximal Femoral Support; How to avoid it?

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Abstract

Objectives: Revision hip arthroplasty is a major surgical challenge and is even more difficult in cases with a deficient proximal femur. Modular uncemented cone body revision femoral stems were introduced as a solution. They have the advantage of optimising joint kinematics by allowing the variable degrees of version, offset and leg length. However, we noticed cantilever failure of such stems, particularly in patients with deficient proximal femoral support. Fatigue fracture of the revision femoral stems should raise questions about its use in patients with insufficient proximal femoral bone support.

Methods: We present a case series of five patients with the cantilever failure of Stryker restoration modular stem conical distal femur prosthesis. These cases were identified during a retrospective review of revision hip surgeries performed at our trust.

Results: The stem failed after an average of 22.6 months post-revision surgery. Primarily, poor proximal femur bone support with a well-fixed distal stem and secondarily high BMI led to this catastrophic failure in the absence of trauma. All five cases were re-revised to Stanmore proximal femoral replacement and achieved good functional outcomes after an average follow-up of seven years.

Conclusion: Proximal femoral bone support should be restored to prevent early cantilever failure of distally fixed proximal modular revision femoral stems. Consider a proximal femoral replacement if we cannot ensure proximal bone support.

Level of evidence: IV

Keywords: Bone support, Cantilever failure, Deficient proximal femur, Modular stem, Proximal femoral replacement, Revision hip

Introduction

Every Revision hip arthroplasty case is unique and complex as the surgeon must deal with compromised soft tissues, retained bone cement, significant bone loss and poor quality of the residual bone. It is even more challenging in patients with deficient proximal femur.[1-4] The proximal femoral deficiency in a prosthetic hip could be secondary to significant proximal femur osteolysis from aseptic loosening, post-debridement for periprosthetic infection or after an extended trochanteric osteotomy.[5] The standard mono-block femoral stems are not helpful in such cases, as proximal and distal stem sizing will often be mismatched. Various implant options have been proposed to manage proximal femoral deficiencies, such as nonmodular long-fluted implants with sufficient distal purchase, extensively coated conical modular implants, distal fixing revision stems, prosthetic allograft composites and proximal femoral replacement.[4,6-8]

First nonmodular extensively coated implants have been introduced for proximal femoral deficiency. However, managing the leg length, tissue tension, and implant bone stability with that implant was challenging.[9-11] Then came

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the long-stemmed fluted components, which reported early failure due to a lack of proximal bone support and were abandoned.[12] The proximal femoral implant allograft composites proved helpful in such cases[13]; however, the inner diameter mismatch between allograft and host bone, time-consuming procedure and implant host-bone junction failures were the limitations. Proximal femoral replacement is another alternative, which will rely on the fixation between the remaining bone and the prosthesis.[14] The implant-allograft composite and proximal femoral replacement ignore the leftover proximal bone and might interfere with the healing due to the bulky reconstruction. Impaction bone grafting has been recommended; however, it is limited to cases with cavitary defects of the proximal femur. It is also complicated by intraoperative fracture and postoperative femoral stem subsidence.[15,16]

When selecting the femoral stems to manage proximal femoral deficiency, the surgeon is expected to choose a system with the best survival under the given circumstances. Selecting an implant system that can deal with uncertainty will be logical. A Modular uncemented cone body femoral stem would be an effective solution in proximal deficient femur patients.[17] Despite the advancement in implant design, technology and surgical technique, the failure of such implants makes the situation even more challenging.[18] We report a case series of cantilever fatigue failure of the Stryker Restoration modular conical femoral stem component in cases with insufficient proximal femoral bone support.

Materials and Methods

As a part of the database review of the outcomes of all revision hip cases, we retrospectively analysed the data from 2005 to 2016. We accumulated data on patients with revision femoral stem failures and identified that cantilever fatigue failures of the femoral stem are the predominant cause in patients with poor proximal femoral support. Survivorship of the primary revision stem, radiological assessment for stress shielding, subsidence, and evidence of loosening were analysed.

We then retrospectively looked at the follow-up of re-revision after the proximal femoral replacement. The follow-up radiographs (to assess aseptic loosening, subsidence, stress shielding and periprosthetic fractures) and functional outcome were scrutinised. The functional outcome was assessed using the University of California-Los Angeles (UCLA) score for the patients still under follow-up. UCLA has a 10-level score ranging from highly inactive (1) to very active (10) patients.[19]

Results

On average, we do 70 revision cases per year. Fifty per cent of them [35 cases] required uncemented modular femoral revision stems, and our unit uses only Stryker restoration modular stems. 7 of the 35 uncemented modular stems failed for multiple reasons, and 5 were cantilever bending failures [0.14%]. We retrospectively collected data on the five cantilever fatigue failure cases, and the patient demography is explained in detail in [Table 1]. All of them were managed with Stanmore proximal femoral replacement. We routinely do not send the retrieved implants for finite analysis unless indicated. Infection was ruled out in all cases with inflammatory markers and multiple [at least 5] intraoperative deep culture samples.

Table 1. Demonstrates summary of patients, indication of surgery, follow-up, and outcome scores

Patients	Age	Sex	Indication for restoration stem	BMI	Proximal modular stem survival	Second Revision procedure	Follow-up second revision	UCLA Outcome score
Patient 1	79	Male	Vancouver B2 Periprosthetic femur fracture	31.4	25 months	Stanmore Proximal femoral replacement	7 years	4
Patient 2	66	Female	Aseptic loosening of the primary hip prosthesis	32	31 months	Stanmore Proximal femoral replacement	6 years	5
Patient 3	71	Male	Aseptic loosening of the primary hip prosthesis	29.4	21 months	Stanmore Proximal femoral replacement	8 years	4
Patient 4	69	Female	Vancouver B2 Periprosthetic femur fracture	31.9	17 months	Stanmore Proximal femoral replacement	7 years	4
Patient 5	67	Female	Vancouver B2 Periprosthetic femur fracture	32.2	19 months	Stanmore Proximal femoral replacement	6 years	4

The general indications of the restoration stem use were cases with severely compromised proximal femoral bone, poor bone quality, and anticipated difficulty adjusting leg length and version in complex revision cases. No allograft or structural bone support was used to reconstruct the proximal femur during the first revision procedure using the Stryker restoration stems. The average age was 70.4 years, the average BMI of the patients was 31.38, and the average primary revision stem survival was 22.6 months. The indication for primary revision in two patients is due to aseptic loosening and in three due to periprosthetic fracture. The follow-up after the second revision to proximal femoral replacement ranges from six to eight years. The UCLA score range at the last follow-up was four to five. We will discuss one patient each from the periprosthetic group and the aseptic loosening group.

Patient 1 is a 79-year-old male with a BMI of 31.4 who presented with sudden pain in the left hip. His left primary hip replacement was done 22 years back with Charnley's hip prosthesis and 20 years later revised for Vancouver B2 periprosthetic fracture using a distally fixed proximal modular stem [Figure 1]. Following the revision, he managed well for the first year, and then unexplained pain started bothering the left hip with difficulty bearing weight. The radiological investigations showed cantilever fatigue failure of the restoration stem in the left hip. The only past medical history was diet-controlled Type 2 diabetes mellitus. Both radiographs and intraoperative findings demonstrated poor remodelling of the proximal femoral bone. Due to the extensive proximal femoral bone loss, which was non-reconstructible, and from the previous experience of cantilever failure in patients with poor proximal femoral support, we decided to proceed with proximal femur replacement. Postoperative recovery was satisfactory; seven years of follow-up showed satisfactory radiological and functional outcomes.

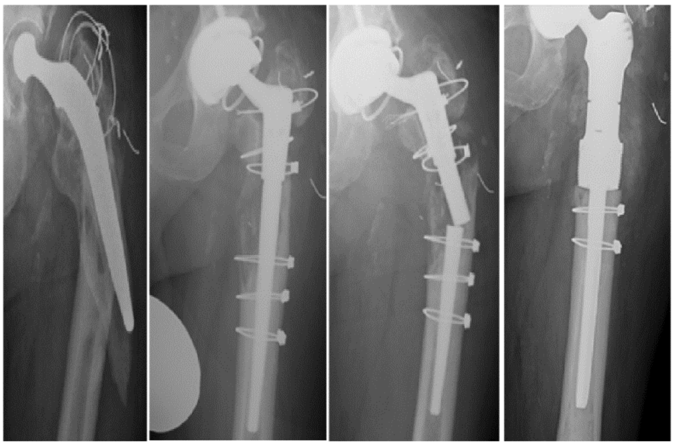

Figure 1. Demonstrates cantilever failure of the proximal modular revision stem performed for periprosthetic fracture. This was treated with Stanmore proximal femoral replacement as proximal bone support was not satisfactory

Patient 2 is a 66-year-old female with a BMI of 32 presented with immediate constant pain in the right hip while walking. She had a primary hip replacement 18 years back and revised for aseptic loosening with the distally fixed proximal modular stem. She had a background history of high blood pressure and chronic musculoskeletal pain. The first revision required extended trochanteric osteotomy to exit the stem, and the poor bone quality led to the use of a proximal modular restoration stem. The radiological evaluation showed cantilever failure of the restoration stem and poor remodelling of the proximal femoral bone [Figure 2]. The second revision was performed with Stanmore proximal femoral replacement, and a satisfactory radiological and functional outcome was achieved at a six-year follow-up.

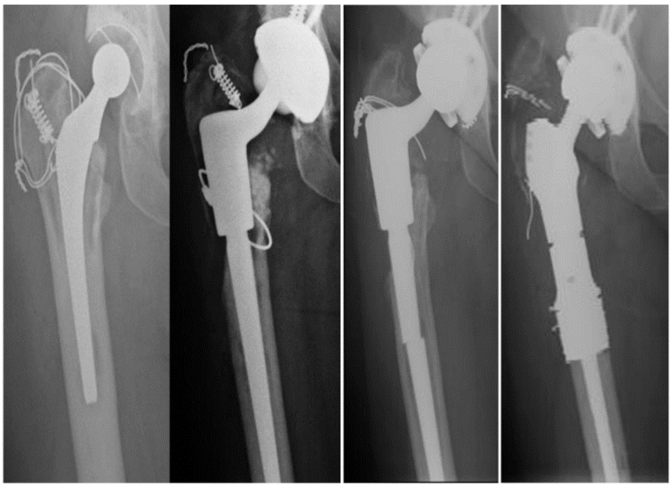

Figure 2. Demonstrates cantilever failure of the proximal modular revision stem performed for aseptic loosening. This was treated with Stanmore proximal femoral replacement as not enough proximal bone support

Discussion

The first mechanical stem fracture due to cantilever failure was reported in 1968 after the early success of Charnley's polished flat back femoral stems from 1962 to 1968.[20] Improved metallurgy and manufacturing techniques resulted in a decreasing trend in the number of revisions due to femoral stem failures. However, stem fractures are still a challenge to revision hip surgeons. In 2018, the Swedish National Joint Registry reported that 158 revision surgeries had been performed for stem fractures since 1999.[21] The 2019 National Joint Registry annual report of England, Wales, and Northern Ireland, with more than 1 million hip replacement data, reported a 0.16% revision rate [confidence interval between 0.15 and 0.17] per 1000 prosthesis years for stem fatigue fracture.[22]

Several stem modifications were introduced to improve metal alloy combinations, size, strength, and geometry. Charnley changed the smooth surface finish to blasted by surface hardening after the stem failures in 1968. In 1971, the stainless-steel stem material was modified to a vacuum-melted, low-carbon type to improve fatigue failures and corrosion resistance. In 1973, the stem geometry was changed to a rounded cross-section (the second-generation Charnley stems), and in 1975, further modification to a third-generation femoral stem with cobra flanged blasted surface was introduced to improve proximal femoral loading.[23] Later, in 1976, Wroblewski proposed a modification in surgical technique by adding a bone block in the medullary canal, augmenting the proximal canal cement pressurisation, and allowing stem subsidence into the bone block, promoting proximal femoral bone loading.[24]

Despite these improvisations, which significantly reduced the fatigue fracture of the stems, a new problem was reported affecting the longevity of the stem: increased incidence of aseptic loosening and progressive loss of proximal stem bone support.[25] As a result of this shift in the complication pattern from stem fracture failure to aseptic loosening, a new design of triple-tapered polished C-stem evolved in 1993. This new design improved the proximal femoral bone loading and maintained the principles of Charnley's low friction arthroplasty.[25] However, these stems are unsuitable for revision cases, especially when a proximal femur is deficient. Hence, the distal fixing proximal modular femoral stems have been introduced for revision cases with proximal femoral bone deficiency.[17]

All five cases we report here are cantilever revision stem [Restoration Modular Cone body femoral stem] failures. The cone body comprises titanium alloy (Ti-6Al-4V ELI), sprayed circumferentially with pure commercial titanium and hydroxyapatite. The cone body provides rotational and axial stability, which is modular, with four vertical offset options adjusting the leg length. The cone body accepts Cobalt Chromium or ceramic V40 femoral heads.

The literature reports several risk factors for fracture of both primary and revision femoral stems. These risk factors include poor proximal femoral support with good distal fixation, high BMI, highly active patients, implant mal-positioning, stress risers and issues with stem geometry, undersized stems or suboptimal calcar cancellous bone removal leading to stem undersizing.[23,26-28] The proximal bone loading of the modular stem is beneficial in contrast to an extensively coated stem, which loads predominantly distal bone. Although the modular restoration stem has been designed for revision cases with severely compromised proximal femur bone deficiency, and it ensures stability by tight diaphyseal fit, it is preferable to maintain as much proximal bone support as possible. If not, the proximal femur reconstruction by bone grafting may be required.[18,29]

In 2005, Busch et al. reported a series of distally fixed uncemented revision femoral stem fractures. They reported proximal femoral bone deficiency, high BMI (more than 30), small diameter stem (less than 13.5mm) and extended trochanteric osteotomy [ETO] as the risk factors for femoral stem fractures. The finite element analysis of the fractured stems proved that the maximum stress point was at the distal end of the ETO, and it matched with the fractured stem site.[18] the common risk factor in all our cases was poor proximal bone support; four patients had a BMI over 30. It is important to note that none of our patients had any contributing trauma, and all had chronic symptoms to the affected hip before stem fracture. The failure mechanism is cantilever forces generated by the unsupported proximal femur and well-fixed distal stem—two of our patients presented with aseptic loosening and required ETO for stem removal during the primary revision. The distal end of the ETO and the periprosthetic fracture site acted as stress risers, contributing to stem fracture at the same site.[18]

Different surgeons performed the first revision and tried to preserve as much proximal femoral bone as possible. However, this was inadequate in the postoperative radiographs, and bone grafting was not attempted. Either should have managed this by impaction bone grafting supporting the calcar[30] or strut allograft augmenting the tension side of the femoral cortex.[18] However, there are reports of increased hoop stresses with impaction bone grafting.[30] Inadequate proximal bone support and BMI of more than 30 in isolation or combination caused the revision stem failures. We used the UCLA score to assess the clinical outcome. Its interpretation could be complex, considering multiple possible dimensions in one response, like frequency, activity type, duration, and intensity of activity. It could cause wide variations in patients' perception of scale. The wide Limits of Agreement [LoA- 2.2-4.4] and previous study recommendations suggest that we should be cautious when comparing individual patients' UCLA scores. In our case series, the majority of our patients reported level 4. However, it may not represent the same level of function.[19,31]

Conclusion

The cantilever revision stem failures due to deficient proximal bone support are a significant challenge to revision hip surgeons. We recommend bone grafting of the proximal femur in such cases, and if this seems inadequate, the proximal femoral replacement would be the best alternative.

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