HIP ARTHROPLASTY: AVOIDING AND MANAGING PROBLEMS

Modular tapered titanium stems in revision arthroplasty of the hip

THE RISK AND CAUSES OF STEM FRACTURE

Tapered fluted titanium stems are increasingly used for femoral revision arthroplasty. They are available in modular and non-modular forms. Modularity has advantages when the bone loss is severe, the proximal femur is misshapen or the surgeon is unfamiliar with the implant, but it introduces the risk of fracture of the stem at the junction between it and the proximal body segment. For that reason, and while awaiting intermediate-term results of more recently introduced designs of this junction, non-modularity has attracted attention, at least for straightforward revision cases.

We review the risks and causes of fracture of tapered titanium modular revision stems and present an argument in favour of the more selective use of modular designs.

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Despite advances in implant fixation and bearing surfaces for primary total hip arthroplasty (THA), with raising incidence of THA, there will be an increasing requirement for revision procedures.1 There have been several advances in the methods of fixation after revision of the femoral component and the materials used. When dealing with deficient proximal femoral bone, the surgeon is reliant on achieving distal fixation. Tapered fluted titanium stems offer some advantages and are emerging as a promising option for un cemented femoral revision,2,3 with good survivorship at intermediate to long-term follow-up.2-5 Unlike fully porous stems which are associated with stress shielding,6-8 it has been shown that when tapered fluted titanium stems are used at revision surgery, proximal bone stock is either maintained or increased.9,10 A recently published mid- to long-term follow-up study of 71 tapered modular titanium stems in revision THA showed bony reconstitution in 75% of the femurs, with the remaining 25% showing stress shielding.11 Their use has also been successfully reported in the management of periprosthetic fractures.9,12-16 We have reported excellent patient reported outcome measures and good survival with this design of stem in femoral revision2 and in the management of periprosthetic fractures.17

The tapered fluted titanium stems are available in both modular and non-modular options. However, modularity comes at the cost of potential failure of the modular junction because of fretting corrosion, and ultimately fracture of the stem.2,18,19

The aim of this article is to review the risks and causes of fracture of un cemented modular tapered titanium femoral stems.

The risks and causes of fracture of modular stems

In our series2 of 27 revision modular tapered fluted titanium stems, we observed five fractures (18.5%) at the modular junction. All were in the standard ZMR design of stem with a so-called “cone proximal body” (Zimmer, Warsaw, Indiana). Fracture at the modular junction was related to increased body mass index (BMI), a stem of small diameter and the use of an extended trochanteric osteotomy for exposure.

This design (ZMR) has subsequently been modified (ZMR extra large (XL)). In the modified version, the junction of the body and stem is strengthened in an attempt to prevent fractures. Several other authors have reported fractures of modular titanium tapered revision stems. It has not been confined to one design.18-21

Lakstein et al19 analysed six mid-stem fractures in cementless modular revision implants (Tivanium alloy; Ti-6Al-4V. Four ZMR XL and two ZMR stems used with allografts; Zimmer, Warsaw, Indiana). Three of these implants were cone bodies with tapered stems, one was a cone body with a porous stem, one was a spout body with a porous stem and one was a spout body with a splined stem. All stems failed between 1 mm to 2 mm proximal to the body-stem junction, thus indicating the
presence of a bending moment during crack initiation. The risk factors associated with a fractured stem included a significantly higher BMI and radiographic evidence of inadequate osseous support at the junctional area of the stem. It was noted that the outer diameter of the stems was between 15 mm and 19 mm, but the mid-stem modular junction had a diameter of only 14 mm in all patients. Scanning electron microscopic (SEM) analysis showed areas of overload as well as fatigue striations, fatigue tears, and subsidiary cracks on the surface of the stems which had fractured. The authors noted that on examination of the circumferential surface of the stem in the vicinity of the fracture, under a stereomicroscope, there was a strip of wear which was 1 mm to 2 mm wide. This is common in failures with a fretting fatigue mechanism.

Efe and Schmitt reported a series of four modular titanium revision stems which were revised for fracture. All had distal tapers, one with additional screws. Two had proximal cones and the two others were porous for one and calcium phosphate coated for the other. All fractures were noted at the tensile anterolateral aspect. The risk factors in this cohort included loosening of the proximal component and a high BMI.

Fink et al reported the use of the Revitan Curved modular titanium fluted revision stem (Zimmer GmbH, Winterthur, Switzerland) in 112 patients (116 revisions) with a full spectrum of proximal femoral defects. This is a dual modular, tapered and distally fixed, uncemented stem manufactured from titanium niobium alloy (TiAl6Nb7). It has a midstem modular junction in which the proximal and distal components are joined by a dual tapered cylinder, made of a cobalt alloy (CoCrMo) to offer high mechanical resistance. At a mean follow-up of 7.5 years (5.3 to 9.1), no fractures of the stem were noted. However, patients with a fracture of this stem requiring revision have been reported. Norman et al reported two fractures of a Revitan stem occurring in the CoCrMo connection part, about 5 mm distal to the visible junction. They proposed a corrosion fatigue mechanism of failure initiated by a crack at the lateral surface of the modular CoCrMo connection. Both patients had a high BMI and were very active. One also had insufficient proximal osseous support. In both patients, the diameter of the fractured connection part was only 12 mm, although the outer diameter of the stem was 22 mm and 20 mm, respectively.

Some authors have investigated the causes of failure of revision stems at the modular junction by the analysis of retrieved specimens. Kop et al compared modular designs in CoCrMo revision stems with titanium revision stems, all with a cobalt-chrome (CoCr) femoral head. They investigated the neck-stem junction in 57 retrieved stems. A total of 30 were CoCr and the rest were titanium stems. A higher percentage (62%) of CoCrMo components had corrosion at the neck-stem trunnion, with 90% showing fretting. In contrast, only 30% of Ti-based components showed corrosion; 50% showed fretting. However, all six stems with cold welding were in Ti based junctions, in which it was difficult to disengage the tapers.

A difference was also noted in the type of machine finish of the trunnion. The CoCrMo devices were more severely corroded with a gramophone finish (100%) compared with the ground devices (26%). In contrast, the Ti-based stems had a greater propensity for corrosion with the ground finish (50%) compared with the gramophone finish (6%).

Rodrigues et al studied the surface of three designs of revision implants with Ti-6Al-4V/Ti-6Al-4V modular taper interfaces looking for evidence of severe corrosion and precipitation of brittle hydrides during fretting-crevice corrosion at the modular connections. The devices were retrieved from patients and studied by means of SEM, x-ray diffraction (XRD) and chemical analysis. The three stems studied were ZMR Porous Revision Hip Components (Zimmer Inc., Warsaw, Indiana), Mallory-Head Modular Calcar Revision stem (Biomet Inc., Warsaw, Indiana) and the S-ROM (DePuy Johnson & Johnson Inc., Warsaw, Indiana). The geometry of the modular junction was different in the three stems, but each was found to be susceptible to the development of severe corrosion. The common features in each design included a crevice geometry where fluids can penetrate, and high interfacial stresses that can induce fretting at the junction of the taper. These features enhance the propagation of cracks, fretting and corrosion that can ultimately lead to hydrogen embrittlement, predisposing to fracture of the stem.

The non-modular solution
Non-modular tapered fluted titanium revision stems are widely available. When they are used in femoral revision, a tapered cone is prepared in the femoral canal. Modular trials are used to confirm the correct length, horizontal offset and proximal version. A definitive non-modular titanium stem with longitudinal flutes is then implanted into the prepared bone bed. The tapered geometry provides axial fixation and the flutes provide rotational stability. The surface of the stem has a grit-blasted rough surface that promotes bone on-growth for fixation. Figures 1 and 2 illustrate the use of a non-modular tapered fluted titanium stem with an extended trochanteric osteotomy for revision of a fractured modular stem.

We have previously reviewed the literature on the use of non-modular tapered titanium fluted stems at mid- to long-term follow-up. A high cumulative survival (between 92% and 98%) of the Wagner SL stem was noted following revision THA. A high percentage of stems had stable implant-bone osseointegration (83.5% to 97%); the remainder (8% to 15%) had stable fibrous fixation. Most patients showed retention of bone or restoration of the proximal femur (63.9%, 88%, 97%, 83.6%, 86.5%), These stems have also been successfully used for periprosthetic fractures and union was observed in all
Discussion

Modular tapered titanium revision femoral components are associated with a risk of fracture of the stem. The use of a cementless, cylindrical, extensively porous-coated, distally-fixed revision femoral stem is associated with a similar rate of complications, and poor proximal bone stock is a risk factor. Newer designs of stem have been introduced in an effort to address this risk, but intermediate term outcomes have yet to be reported. It remains to be confirmed that these efforts have been successful. The incidence of this complication is low, but the risk increases in patients with a high BMI, a high level of activity, a small medullary canal (hence small stem diameters) and those with severe bone loss and poor proximal bony support for the stem, especially medially. Further analysis of risk factors and the causes of fracture of a stem is limited by the paucity of studies which have reported this complication with the use of the newer generation of stems at revision.

Modularity is desirable in complex femoral revisions, and in the hands of surgeons who are unfamiliar with the surgical nuances of tapered, fluted, titanium stem designs. With the increasing emergence of evidence that non-modularity is associated with consistently encouraging results, it is appropriate to consider this type of stem in many, if not most, stem revisions when the use of such a design is appropriate.

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References


Fig. 1
Pre-operative radiograph of a patient who presented with fracture of a modular tapered fluted titanium stem at the modular cobalt alloy junction between the metaphyseal and diaphyseal components. This is demonstrated by the subtle angularity between the modular components at this junction and the newly developed divergent radiolucent line in Gruen Zone 1.

Fig. 2
Radiograph showing successful revision of the fractured modular stem after extended trochanteric osteotomy using a non-modular tapered fluted titanium stem.

patients when the non-modular tapered titanium stems were used for revision following a periprosthetic fracture.9,12

No fractures of a non-modular stem have been reported at mid to long-term follow-up. The main complications noted with the use of these stems were subsidence, dislocation and intra-operative fractures; the incidence of these complications was 2% to 5%.24


