Research Square

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The Survivorship of Revision Total Hip Replacement With Severe Proximal Bone Deficiency Using a Modular Taper Fluted Prosthesis

Siddharth Govilkar (siddoc1984@yahoo.co.uk)
Robert Jones and Agnes Hunt Orthopaedic Hospital https://orcid.org/0000-0001-6895-460X
Maulik Gandhi
Robert Jones and Agnes Hunt Orthopaedic Hospital
Davinder Bhachu
The Robert Jones and Agnes Hunt Orthopaedic Hospital
John-Paul Whittaker
Robert Jones and Agnes Hunt Orthopaedic Hospital
Christopher Evans
Robert Jones and Agnes Hunt Orthopaedic Hospital
Richard Spencer-Jones
Robert Jones and Agnes Hunt Orthopaedic Hospital

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Abstract

Background

Contemporary uncemented femoral revision hip systems have become commonly used over the past decade and have enabled the reconstruction of leg length, offset and anteversionas independent variables through the use of modular junctions. Modular junction failures between the proximal body and distal stem have been described withrevision systems, although this is rare. We sought to identify the survivorship of one revision system in a salvage arthroplasty scenario where no host bone support of the modular junction was present.

Methods

From a series of 136 patients, 15 patients (16 hips) were identified without host bone support of the modular junction with a mean radiological follow up of over 6 years(76 months +/- 35 months).

Results

There have been no cases of prosthetic fracture over the follow-up duration, withtwo revisions performed for reasons of aseptic loosening and infection. The mean BMI of the study group was 30.2 with 78% of the cohort classified as overweight or obese.

Conclusion

It is well recognised that, host bone support of the modular junction is preferable, however the satisfactory outcomes over the midterm in these complex patients suggests that modular revision systems remain an option.

Background

According to the National Joint Registry Report 2019, revision hip replacements contributed 10% of the hip arthroplasty workload in the UK totaling 101 561 primary & revision hip replacements [1]. The development of uncemented modular femoral revision hip systems have allowed for fixation in distal host bone whilst allowing for independent length control of offset and anteversion through the use of taper junctions with the proximal segment of the revision prosthesis [2].

In this study, we examined our experience with a single design, tapered, fluted, modular, titanium, uncemented revision system. A number of published series highlights the success of the system presented in this study with midterm follow-up [24–27].

Our aim was to identify mechanical failures at the proximal body-distal stem modular junction of the revision system (Stryker® Cone-Conical system, Stryker, Newbury, United Kingdom) in patients with severe loss of proximal host bone. We sought to clarify whether the continued use of the system in cases

with absent proximal host bone coverage over the proximal body-distal stem modular junction is justified, not least given the alternative surgical options of a proximal femoral replacement, structural bulk allograft-prosthesis composite or revision monoblock stem[28–31].

The failure of differing designs of modular junction have been described as occurring through a multitude of mechanisms including corrosion (fretting/galvanic/crevice/pitting/inter-granular) [3–5] and mechanical failure of modular, distal-fit systems [6–9]. In the early years of these devices, systemic failures led to the withdrawal of a similar revision system [10]. Mechanical failure occurs through fatigue with repetitive cyclical loading of the modular junction between the proximal body and the distal stem [6], which represents the most biomechanically stressed area of the revision. Risk factors for failure of both titanium alloy [7, 8] and cobalt chrome [11] revision femoral components include excessive body weight, inadequate proximal bony support, poor preoperative bone stock, osteolysis, loosening, high levels of physical activity, and/or implant under-sizing [7, 8, 11, 12].

Since mechanical failures were reported in the early designs of modular, distal-fit systems [6–10], the modular junction design has evolved, incorporating a strengthened junction [9]. Reinforcing the proximal body-distal stem modular junction by using a strengthened junction design and advances in metallurgy, have reported reduced the rate of failure from 18.5–0% [9]. These results have encouraged the use of modular revision hip arthroplasty implants with reinforced junctions, particularly in patients with known risk factors for failure [8, 9]. Manufacturing methods used to improve the taper strength of titanium-based femoral prostheses can be either mechanical (swaging, burnishing and shot peening) or non-mechanical (heat treatment, nitride impregnation and anodizing) [13]. Mechanical treatments affect the surface to a depth of approximately 0.25 mm – 0.50 mm [14, 15], whilst non-mechanical treatments affect to a depth of less than 0.1 mm [13]. The increased depth conferred by mechanical treatment ultimately enhances the fatigue strength of the taper when compared to non-mechanical treatment [16].

It is unclear if the improved mid-term survivorship is the result of the strengthened junction design only (withstanding junction failure), or if there is a pre-requisite that the revision prosthesis modular junction must be covered by host bone. Rodriguez et al. concluded “failure to achieve osseointegration of the “proximal segment” did not compromise clinical function or distal function, but due to risk of implant fracture, regular follow up is desirable” [22]. There is a single report detailing the use of tapered, fluted, modular titanium stems with severe femoral bone loss [23]. In that study, one of 16 cases required revision for septic loosening [23]. Other published studies do not specify the degree of host bone support of the modular junction between the proximal body and distal stem immediately post operatively, although radiological evidence of loosening around the proximal components at the time of proximal body-distal stem junction failure have been observed in some cases [6, 8].

There are published case series involving modular, distal fit revision systems that have demonstrated a greater than 5-year mean survivorship with no reported modular failures, although host bone support of the modular junction is unclear [17–20]. We believe the increased strength at the proximal body-distal stem junction and the surgical technique to cover this junction with host bone may have contributed for

the decrease in mechanical failures reported. The strengthened design at the proximal body-distal stem modular junction is intended to help decrease local stress. Maximal stress is expected, even with a strengthened junction, when there is no proximal bony coverage of the prosthesis [21].

Methods

A single design modular taper fluted femoral revision system was assessed in this study, in patients with severe proximal femoral bone loss. This was a retrospective, observational study, approved by the local research department advising no further ethical approval was required [32].

A consecutive series of patients with femoral bone deficiency (classified as Paprosky IIIB or IV [33]) receiving revision hip surgery using the modular taper fluted modular titanium system were identified. Two observers independently reviewed the host bone coverage over the proximal body-distal stem modular junction using postoperative radiographs. Absent support of the modular junction by host bone was defined as the lack of bone proximal to, and at the level of the proximal modular junction on at least 3 prosthetic surfaces viewed on antero-posterior (AP) and lateral radiographs of the proximal femur. If there was a consensus that there was deficient proximal host bone coverage over the modular junction at a minimum of two years of follow-up, the patient was entered into the study. The Kappa inter-observer agreement (κ) between the two observers was calculated using Cohen's Kappa with squared weighting (statistics software R, version 3.0.3 (R Foundation for Statistical Computing)). Radiographs of representative cases from our study group, with modular proximal body-distal stem junction unsupported by host bone are shown in Fig. 1. The operation record, clinical notes, and radiographs of study participants were reviewed. The primary endpoint was radiographic evidence of proximal body-distal stem modular junction failure. The secondary endpoint was revision for any other cause. All procedures were performed by, or under the supervision of, consultant revision hip surgeons using the surgical technique described by the manufacturer. The results are presented as means ± standard deviations (SD).

The revision system used in our study consists of a distal fluted stem and proximal conical body made using a titanium alloy, Ti-6 Al-4V (Restoration Cone Conical, Stryker). The conical proximal bodies are circumferentially plasma sprayed with pure titanium and then over-sprayed with hydroxyapatite. A number of cone body diameters and lengths with variably sized offset options are available to allow correction of vertical and horizontal offsets. The manufacturing process for the system is designed to provide rotational and axial diaphyseal stability. The modular taper junction involves a "shot peening process" (mechanical treatment) to harden the taper junction and enhanced fatigue stress.

Results

Fifteen of 136 patients (representing 16 hips) receiving a single design modular Restoration revision hip prosthesis over a seven-year period met the inclusion criteria (Table 1). Details of the implant components used are summarized in Table 2. There was excellent and significance Kappa inter-observer agreement between the two observers' radiographic assessment of proximal host bone coverage (κ =

0.757, $p < 0.0001$). We present the results of clinical with radiographic follow-up and clinical follow-up in Table 1.

Table 1
Patient Demographics.

Case	Age at surgery in years	BMI	Indication for surgery	Implant Survivorship (months)	
				Clinical & Radiographic	Clinical only
1	69.8	29	Aseptic loosening	112	112
2	58.2	33.5	2nd stage for infection	81	84
3	69.8	35	Painful girdlestone	57	86 (died)
4	67.1	21.4	Aseptic loosening	1	25 (died)
5	38.7	31	Aseptic loosening	92	95
6	63.1	24	2nd stage for infection	43* (revised)	43* (revised)
7	71.8	27.5	Aseptic loosening	115	115
8	75.3	27	2nd stage for infection	111	111
9	72.5	29	Aseptic loosening	97	97
10	80.4	26	Aseptic loosening	68	68
11	64.1	29	2nd stage for infection	117	117
12	65	31.2	2nd stage for infection	73	73
13	64.2	34	Aseptic loosening	28* (revised)	28* (revised)
14	64.2	36.5	2nd stage for infection	59	59
15	75.8	41	Aseptic loosening	42	80 (died)
16	79.7	27.8	Periprosthetic fracture	115	121

Table 2
Details of implant components used per case (* original acetabulum retained).

Case	Proximal body size	Distal stem (length x diameter)	Stem (straight or bowed)	Femoral head (material, size)	Acetabular component size
1	23 + 10	155 × 17	Straight	SS, 28(+ 4)	40
2	25 + 20	195 × 17	Straight	CoCr, 40(+ 8)	58
3	20 + 0	195 × 14	Straight	CoCr, 44(+ 4)	70
4	27 + 60	195 × 21	Straight	CoCr, 40 (-4)	58
5	29 + 0	155 × 15	Straight	CoCr, 28(-4)	58
6	21 + 10	155 × 15	Straight	CoCr, 28 (+ 0)	50*
7	31 + 30	235 × 20	Bowed	SS, 36 (+ 0)	66
8	25 + 0	155 × 16	Straight	CoCr, 40 (+ 0)	58
9	21 + 0	155 × 14	Straight	CoCr, 40 (-4)	56
10	25 + 0	225 × 15	Straight	CoCr, 36 (+ 0)	54
11	34 + 30	155 × 19	Straight	CoCr, 32 (+ 12)	64
12	27 + 20	235 × 15	Bowed	CoCr, 28 (+ 4)	56
13	21 + 10	155 × 15	Straight	CoCr, 40 (+ 0)	60
14	23 + 20	195 × 18	Straight	CoCr, 36 (+ 0)	60
15	19 + 10	195 × 17	Straight	CoCr, 36 (+ 5)	56
16	23 + 40	155 × 17	Straight	SS, 22.225 (+ 0)	40*

Seven females and eight males were in the study group; one female had revision hip surgery, resulting in a final study group of 16 revision hip replacements. The mean age at surgery was 67.5 years (38.7 years to 80.4 years; SD 9.9 years). The mean survivorship of the unsupported junction to most recent follow-up with radiographs was over 6 years (1 month to 117 months; mean 76 months +/- 35 months). The mean survivorship of the unsupported junction to most recent clinical follow-up with documented survivorship was just under 7 years (25 months to 121 months; mean 82 months +/- 31 months). The mean body mass index (BMI) was 30.2 (21.4 to 41 +/- 4.9), with 78% of patients being categorized as overweight or obese.

No proximal body-distal stem junction failures were identified during the follow-up period. Revisions were required for reasons unrelated to the femoral prosthesis in two cases: the first for aseptic loosening of an

acetabular component and the second for infection. Revision surgery was therefore required in 11.8% of cases.

Overall, stem survival was 100% at a mean follow-up of over 5 years (64.8 months +/- 32 months) and implant survival due to any cause was 88.2%.

Discussion

Revision hip surgery is challenging, especially when there is significant proximal femoral bone loss [2]. Surgical options in these arthroplasty salvage cases may include proximal femoral allograft-prosthesis composite reconstruction, proximal femoral replacement, and uncemented distal stem fixation [24]. Although the clinical outcomes of uncemented distal fit femoral stems are generally favorable [9, 24, 34–37], reports have described mechanical failures at the modular junction [3, 4, 8] or in areas where laser etching of the stem has been used [9]. There is evidence that proximal bony reconstitution can improve clinical outcomes, quality of life measures, and implant survivorship [8, 26, 27, 34–38].

The stem survival of the revision system we used has been reported to be 96% at a mean follow-up of 42 months [24], and 94% at a mean follow-up of 4.5 years [25]. Holt et al reported on 46 patients with a mean BMI categorized as overweight and included patients with host bone support of the proximal body-distal stem modular junction [24]. It is our opinion that our obese patient cohort placed more stress at the proximal body-distal stem modular junction by having a higher mean BMI and no host bone support at the modular junction. Palumbo et al reported on 18 patients with a follow-up period similar to ours, however they do not report on the patients' weight or post-operative host bone coverage of the junction [25].

Time from surgery to modular junction or stem failure of other comparable revision stems reveals a mean failure time of 47 months (+/- 25 months) [8], with our longest single case including radiographic follow-up being 115 months.

We have not identified any prosthetic failures to the femoral component in our study despite the longer mean follow up time, although it is well recognized that mechanical failure is related to the dimensions of the device, material properties and the applied mechanical forces over time.

Therefore the authors suggest caution with the use of smaller stem diameters particularly in patients with expected high demands or raised BMI.

A lack of proximal femoral host bone leaving the proximal body-distal stem modular junction unsupported immediately post operatively has been identified as a risk factor for proximal body-distal stem modular junction failures in multiple revision systems currently used in clinical practice [7, 8, 11]. This suggests that the construction of this system is able to withstand fatigue of the proximal body-distal stem modular junction. There is limited evidence in current literature reviewing the clinical and

radiological survivorship of total hip replacement revisions beyond a mean of 5 year follow up, in patient with severe proximal bone loss [24–27].

Although underlying risk factors always need to be considered before, during, and after revision, our results provide reassurance that the proximal body-distal stem junction of the contemporary revision prosthesis can prevent interface failures and can be used with confidence over the medium term even in the absence of proximal femoral bony support.

Abbreviations

BMI
Body Mass Index

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Figures

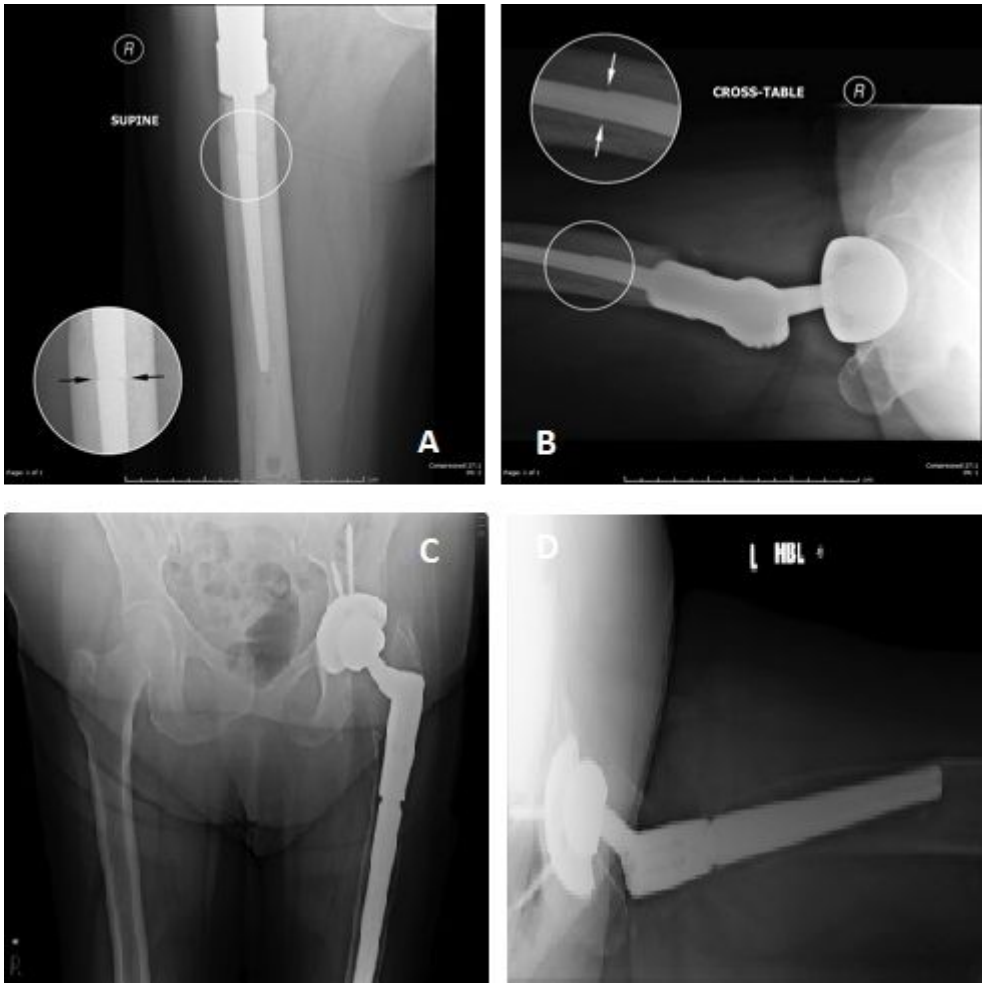

Figure 1

(A-D) – Plain Radiographs of Representative Cases with Unsupported Modular Proximal Body-Distal Stem Junction.

Supplementary Files

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