Mid-term outcomes of titanium modular neck femoral stems in revision total hip arthroplasty

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Background: Modular stems have been widely studied as they allow intraoperative adjustments (offset, anteversion, limb length) to better restore hip biomechanics. Many authors reported outcomes of revision total hip arthroplasty (THA) using modular stems with metaphyseal-diaphyseal junctions, however, little is known about modular neck femoral stems (MNFS) with metaphyseal-epiphyseal junctions. We therefore aimed to report outcomes and implant survival of a MNFS in a consecutive series of revision THA at a minimum follow-up of 5 years.

Methods: We reviewed a consecutive series of 28 revision THAs performed between February 2010 and March 2012 using an uncemented MNFS. The final study cohort included 25 patients living with their original components, at a mean follow-up of 68.4±7.4 months and aged 67.7±11.6 years at index operation.

Results: The Harris Hip Score (HHS) improved from 39.1±19.2 pre-operatively to 78.1±18.3 post-operatively, and the Postel Merle d'Aubigné score (PMA) improved from 9.8±3.0 pre-operatively to 14.8±2.8 post-operatively. The postoperative limb length discrepancy (LLD) was >10 mm in 18% of the hips. There were no significant differences of femoral offset and neck shaft angle (NSA) between operated and contralateral hips. Two hips (8.0%) showed new periprosthetic radiolucent lines. Periprosthetic fractures (PPF) occurred in 3 hips (12%). No subluxations, dislocations or implant breakages were reported. One revision (3.6%) was performed with retrieval of the revision stem for infection. The Kaplan-Meier (KM) survival at 5 years, using stem revision as endpoint, was 96.0%.

Conclusions: The Optimal® MNFS provided a satisfactory survival and clinical outcomes at 5 years, with no noticeable adverse effects resulting from the additional modular junction.

Keywords: Revision total hip arthroplasty (revision THA); modular stem; modular neck; implant survival; clinical and radiographic outcome

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Introduction

The incidence of revision total hip arthroplasty (THA) is increasing worldwide due to an aging population and expansion of indications for primary THA (1). It has been estimated in 2016 that revision THA represented nearly 15% of all hip arthroplasty procedures in the United States and is projected to increase by 137% by 2030 (1). Different stem designs have been proposed for revision THA, including standard (primary) stems, long stems, modular or

Table 1 Patient characteristics

Variables	Patients (n=28 hips)
Gender	
Male	15 (53.6)
Female	13 (46.4)
Revision	
Stem only	11 (39.3)
Stem and cup	17 (60.7)
Femoral bone loss	
Paprosky I	13 (46.4)
Paprosky II	6 (21.4)
Paprosky IIIA	4 (14.3)
Paprosky IIIB	4 (14.3)
Paprosky IV	1 (3.6)
Operated hip	
Right	17 (60.7)
Left	11 (39.3)
Age at index operation	68.1±12.5; 69.8 (36.5–87.2)
BMI	30.5±7.0; 29.0 (22.2–53.0)

Data are presented as n (%), or mean ± SD; median (range). BMI, body mass index.

Figure 1 The uncemented, anatomic, modular neck, femoral titanium stem of the Optimal® hip system.

distally locked stems, either cemented or uncemented (2-4).

Modular stems have been studied by many authors as they allow intraoperative adjustments of femoral neck anteversion, offset, and limb length to better restore muscle tensions and hip biomechanics (5-8). In primary THA, several modular stems have been associated with corrosion or fracture at their junctions, though models made of titanium bodies and necks seem to obviate these problems, and grant satisfactory mid-term survival and excellent clinical outcomes at 10 years (9).

Many authors reported outcomes of revision THA using modular stems with metaphyseal-diaphyseal junctions, and though several authors investigated modular neck femoral stems (MNFS) with metaphyseal-epiphyseal junctions for primary THA, only one study evaluated their outcomes for revision THA (10). The purpose of this study was therefore to report clinical outcomes and implant survival of a MNFS in a consecutive series of revision THA at a minimum follow-up of 5 years.

Methods

The authors reviewed a consecutive series of revision THAs performed between February 2010 and March 2012. The inclusion criteria covered both single- and multi-stage revision THAs performed using an uncemented modular stem (Optimal®, Amplitude, Valence, France). The exclusion criteria were femoral or acetabular deformities, documented prior to the index THA, due to congentital hip dysplasia or previous fracture malunions. Eleven hips underwent femoral revision only, while seventeen hips underwent femoral and acetabular revisions, for which an uncemented dual mobility cup was used (Saturne®, Amplitude, Valence, France) (*Table 1*).

Implant

The femoral stem used has an anatomical design with 4° metaphyseal anteversion and anterior curvature of femoral shaft. The stem body is made of anodized titanium and is coated with hydroxyapatite (HA) along its superior two-thirds (*Figure 1*). The stem body is available in standard and long versions and can be locked distally with one or two threaded pins. The modular necks are also made of anodized titanium and feature two Morse tapers: the upper for the neck-to-head junction and the lower for the neck-to-body junction. The modular necks are available in different lengths, anteversions and neck shaft angles (NSA), allowing

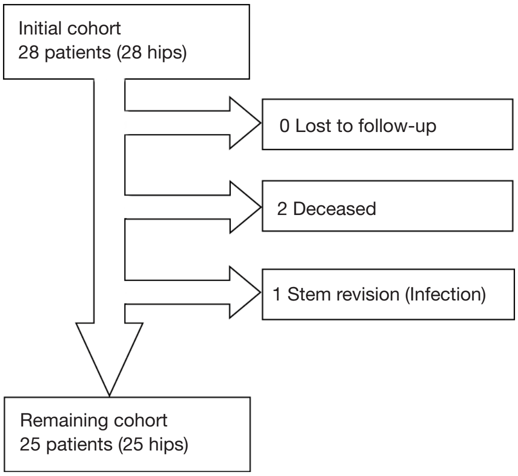

Figure 2 Flowchart detailing inclusion and exclusion of patients from the original cohort.

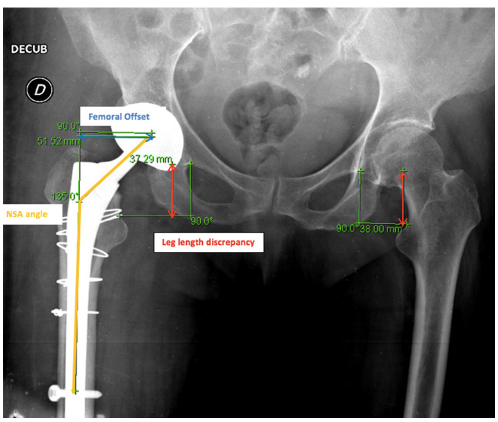

Figure 3 Postoperative radiographic measurements of the femoral offset (blue), neck shaft angle (NSA, yellow), and limb length discrepancy (red).

24 different combinations for hip reconstruction.

Surgical technique

The indications for revision of the stem were femoral aseptic loosening in 15 hips (53.6%), femoral periprosthetic fracture (PPF) in 10 hips (35.7%), and infection in 3 hips (10.7%). Femoral bone loss of Paprosky (11) grade I in 13 hips (46.4%), grade II in 6 hips (21.4%), grade IIIA in 4 hips (14.3%), grade IIIB in 4 hips (14.3%), and grade IV in 1 hip (3.6%). All patients were operated through a posterolateral approach. The femoral stem implantation is divided in two steps: the intramedullary implantation of the stem with a classic 'press-fit' method, and the extramedullary choice of modular neck to reconstruct the native centre of rotation. Stems were locked distally using one threaded pin in 1 hip (3.6%) and using two threaded pins in 19 hips (67.9%).

Rehabilitation

Structured physical therapy with passive and active motion exercises of the hip started the day after surgery and continued during hospitalization. Patients could walk using two crutches or a walker with partial weight-bearing on the operated limb for 6 weeks post-operatively and full weight bearing thereafter.

Postoperative assessment

Patients were evaluated during their routine follow-up visits. If patients were deceased, their general practitioner was contacted to confirm the date and cause of death, and whether any of their THA components had been revised. From the initial 28 patients, 1 patient (3.6%) had isolated stem revision, and 2 patients (7.1%) had died with their original stems in place (*Figure 2*). This left a study cohort of 25 patients living with their original components at a mean follow-up of 68.4±7.4 months (range, 60.0–82.0 months), aged 67.7±11.6 years (median, 68.8 years; range, 36.5–83.7 years) at index operation that were assessed both clinically and radiographically.

The final cohort was clinically evaluated using the Harris Hip Score (HHS) (12) and the Postel Merle d'Aubigné score (PMA) (13). Patients were evaluated radiographically, on anteroposterior plain radiographs, to assess NSA, femoral offset, limb length discrepancy (LLD, measured by the distance between the U-landmark to the lesser trochanter), as well as the position of the centre of rotation in the horizontal and vertical directions according to the Pierchon index (14-16) (*Figure 3*). Radiolucent lines >2 mm wide and LLD ≥10 mm were considered as adverse radiographic findings. All X-rays were performed in the standing position with controlled rotation of the lower limb. The anatomical parameters of the operated hip were compared to the contralateral native hip using Centricity™ software (GE Healthcare, Barrington, IL, USA). Radiological features suggesting corrosion due to modular necks were defined as periprosthetic proximal femoral osteolysis in Gruen zones 1

Table 2 Patient clinical scores

Clinical scores	Pre-operative		Post-operative		P value
	Mean ± SD	Median (range)	Mean ± SD	Median (range)	
Harris Hip Score	39.1±19.2	35.0 (7.0–83.0)	78.1±18.3	81.0 (26.0–100.0)	<0.001
Postel Merle d'Aubigné score	9.8±3.0	10.0 (4.0–15.0)	14.8±2.8	16.0 (8.0–18.0)	<0.001
Pain	1.8±1.4	1.0 (0.0–6.0)	4.2±1.9	5.0 (0.0–6.0)	
Function	3.0±1.6	3.0 (0.0–6.0)	4.4±1.6	4.5 (1.0–6.0)	
Mobility	5.3±1.0	6.0 (3.0–6.0)	5.9±0.3	6.0 (5.0–6.0)	

Table 3 Radiographic hip architecture

Variables	Operated		Contralateral		P value
	Mean ± SD	Median (range)	Mean ± SD	Median (range)	
Neck shaft angle	130.7±19.2	131.3 (120.0–138.0)	132.1±5.1	132.1 (120.0–140.0)	0.381
Femoral offset	52.2±8.0	50.6 (38.1–74.7)	51.3±10.0	50.8 (32.8–77.7)	0.770

and 7 (17). PPF were classified according to Masri *et al.* (18) (Vancouver classification).

Statistical analysis

Shapiro-Wilk tests were used to assess the normality of distributions. Differences between operated hips and contralateral hips were evaluated using the *t*-test for gaussian quantitative data or using Wilcoxon rank-sum test for non-gaussian quantitative data. Paired *t*-test (for gaussian data) or Wilcoxon signed rank test (for non-gaussian data) were used to evaluate differences between pre- and postoperative quantitative data. Implant survival was assessed using the Kaplan-Meier (KM) method with stem revision for any reason as endpoint. Statistical analyses were performed using R version 3.2.3 (R Foundation for Statistical Computing, Vienna, Austria). P values <0.05 were considered statistically significant.

Results

Clinical and Radiographic assessments

The HHS improved from 39.1±19.2 (median, 35.0; range, 7.0–83.0) preoperatively to 78.1±18.3 (median, 81.0; range, 26.0–100.0) post-operatively (P<0.001) (*Table 2*). Likewise, the PMA score improved from 9.8±3.0 (median, 10.0; range, 4.0–15.0) preoperatively to 14.8±2.8 (median, 16.0; range, 8.0–18.0) post-operatively (P<0.001).

At last follow-up, the mean LLD was 4.3±5.0 mm (median, 1.5 mm; range, 0–16.4 mm). The LLD was >5 mm in 45.5%, and >10 mm in 18%. The HHS was almost equal in hips with LLD >10 mm than to those with LLD <10 mm (78.5±11.6 *vs.* 78.2±20.3, respectively; P=0.701). There were no significant differences of femoral offset and NSA between operated and contralateral hips (*Table 3*).

Radiolucent lines were observed distally (Gruen zones 3, 4 and 5) around 5 stems (20.0%) and proximally (Gruen zones 1, and 7) around 1 stem (4.0%). Considering the pre-revision osteolysis, only 2 hips (8.0%) showed new periprosthetic radiolucent lines, both of which were located distally.

Complications

One revision (3.6%) was performed during the study period, with retrieval of the revision stem for acute periprosthetic infection, which occurred 27 months after surgery. Periprosthetic fractures (PPF) occurred in 3 hips (12%), of which 2 were graded B2 (8.0%) and 1 graded C (4.0%). No subluxations, dislocations or implant breakages were reported.

Survival

Using the KM method and stem revision for any reason as endpoint, survival at 5 years was 96.0% (95% confidence

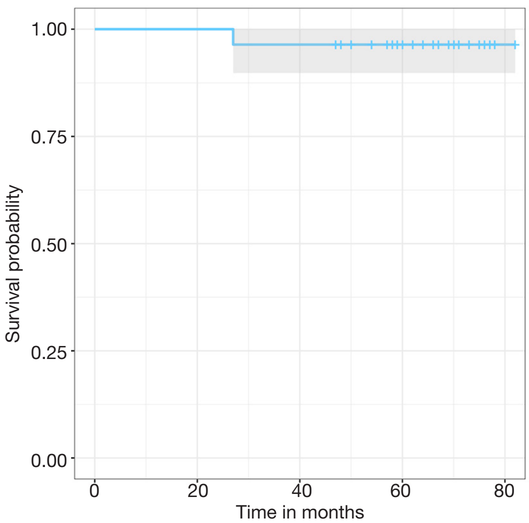

Figure 4 Kaplan-Meier survival curve considering revision of the femoral stem for any reason as endpoint.

interval, 90% to 100%) (*Figure 4*).

Discussion

The principal finding of this study was that using MNFS in revision THA demonstrated satisfactory clinical outcomes and survival rate at a minimum follow-up of 5 years. To our knowledge, this is the first study to report clinical and radiographic outcomes of revision THA using femoral stems with metaphyseal-epiphyseal modular junctions.

Our reported postoperative HHS of 78.1 and PMA of 14.8 compare well with scores published in other studies of revision THA using modular stems: 69.0–93.0 and 7.0–16.7 respectively (*Table 4*). In our series, LLD was <5 mm in 54.5% of the hips, which is within the range of 28–78% reported in the literature (8,24). LLD >10 mm was observed in 4 hips but was not associated with inferior clinical scores.

Badarudeen *et al.* (39) estimated the global rate of failure in revision THA to be around 15.8%. Springer *et al.* (40) found that instability was the main cause for failure of revision THA in 35% of the cases. There is still a controversy as to whether modular femoral stems reduce dislocation rates after revising a failed primary THA. Restrepo *et al.* (8) reported a low dislocation rate of 3%, and attributed it to the use of modular stems, which allowed accurate restoration of the hip architecture. Likewise, Wirtz *et al.* (41) reported dislocations in 3.5%, which had been successfully managed by exchanging the modular necks, without removing the stem body. However, dislocation rates were found to be higher in other revision THA series using modular stems, ranging from 9% (25) to 19% (28). Regis *et al.* (42) stated that modular stems alone are not effective in decreasing the risk of dislocation. In our series, the absence of dislocations could be attributed to adequate restoration of the native hip architecture allowed by the modular necks (used for all hips) and to the improved joint stability granted by dual mobility cups (used in 60% of hips) (43).

Postoperative PPF occurred in 3 hips (12%) and were of grade B in 2 hips and of grade C in 1 hip. Our PPF rate is higher than the 2–5% rate reported by Restrepo *et al.* (8) and Huddleston *et al.* (21). This higher rate can be due to the use of anatomic stems, which are known to be more filling than straight stems (44). Moreover, it is worth noting that one of the three hips with PPF had severe preoperative bone loss (Paprosky IIIb).

We found no new radiolucent lines in the femoral metaphysis suggesting that there were no corrosion signs at the neck-stem junction. Such as previous published studies (8,25,37), we found no complications related to the Morse taper junction. Fretting and corrosion occurred on all modular neck-stem regardless of design, but homogenous metal couples suffered less from corrosion than mixed couples (45). As in our series, titanium-titanium junctions appeared to be a suitable solution to corrosion issues (45-48).

The MNFS KM survival at 5 years of 96% is within the 72–97.2% survival range at 3.3–7 years reported in other studies (19,23,27,30,34,38) using modular stems revision for any reason as endpoint (*Table 4*). It is worth noting that most of these published studies on revision THA investigated a femoral stem designed with a metaphyseal-diaphyseal junction, while we analysed a femoral stem designed with a metaphyseal-epiphyseal junction (modular neck). It is still controversial whether modular stems in revision THA are more efficient than monolithic stems. Huddleston *et al.* (21) reported lower revision rate for modular stems, whilst Mertl *et al.* (10) found a higher rate of failure for MNFS. However, compared to monolithic stems, modular implants greatly simplify strategies for revision THA and following failures of revision as the modular neck can be removed, facilitating exposure and replaced easily to adapt offset, limb length and NSA while leaving the intramedullary part of the stem stably fixed within the femur, which has relatively good bone quality at mid-term follow-up (42,49-51).

The current study has some limitations. First, it is a retrospective study with a small sample size. However,

Table 4 Clinical outcomes and survival of uncemented modular femoral stems in revision THA at midterm follow-up (FU<10 years)

Stem modularity	Author	Year	No. of patients	Stem	Manufacturer	Bone loss[d]	FU years	PMA		HHS		KM[a]		Re-revision rate[a]
								Preop	Postop	Preop	Postop	Years	%	%
Metaphyseal-epiphyseal (Modular neck)	This study	2018	28	Optimal	Ampltitude	I–IV	5.6	9.6	14.8	38.1	78.1	5.0	96.0	3.6
	Mertl *et al.* (10)	2011	205	Ultime	Wright Medical	II–IV[e]	4.5	–	–	–	–	–	–	–
Metaphyseal-diaphyseal	Smith *et al.* (19)	2016	115	Restoration	Stryker	I–IV	6.1	–	–	–	–	6.1	82.0	14.8
	Wronka *et al.* (20)	2016	47	Revitan	Zimmer	I–III[b]	4.7	–	–	–	–	–	–	4.0[b]
	Wronka *et al.* (20)	2016	57	MP	Waldemar Link	I–III[b]	4.7	–	–	–	–	–	–	1.8[b]
	Amanatullah *et al.* (2)	2015	192	MP	Waldemar Link	III–IV	6.4	–	–	–	69.0	–	–	4.3
	Huddleston *et al.* (21)	2016	150	ZMR	Zimmer	I–III[a]	4.3	–	–	–	–	–	–	7.0
				Restoration	Stryker									
				MDF	Smith & Nephew									
	Tangsataporn *et al.* (22)	2015	97	ZMR	Zimmer	II–V[h]	2.8	–	–	–	–	–	–	7.1
	Menciere *et al.* (23)	2014	29	Contact*	Wright Medical	0–IV[e]	6.3	11.7	16.7	44.6	88.2	6.3	72.0	–
				Profemur-L	Wright Medical									
	Stimac *et al.* (24)	2014	125	Restoration	Stryker	I–IV	4.3	–	–	51.4	85.7	–	–	1.2
	Jibodh *et al.* (25)	2013	52	ZMR	Zimmer	I–III[b]	7.0	–	–	–	81.0	5.0	94.0[b]	6.0
	Klauser *et al.* (26)	2013	63	MP	Waldemar Link	I–III	8.5	–	–	–	83.0			1.6
	Skytta *et al.* (27)	2012	408	MP	Waldemar Link		5.0	–	–	–		5.0	78.0	–
	Weiss *et al.* (28)	2011	90	MP	Waldemar Link	I–IV	6.0	–	7.0		78.0	–	–	2.1
	Canella *et al.* (29)	2010	30	ZMR	Zimmer	II–IV	2.0	–	–	39.0	93.0	–	–	0.0
	Restrepo *et al.* (8)	2011	122	Restoration	Stryker	I–IV	4.0	–	–	62.0	77.0	–	–	–
	Lakstein *et al.* (30)	2010	69	ZMR	Zimmer	I–IV	7.0	–	–		72.0	10.0	93.8	5.5
	Philippot *et al.* (31)	2009	43	REEF	Depuy Synthes	I–IV[e]	4.8	6.0	14.5	–	–	5.0	97.7[b]	–

Table 4 (*continued*)

Table 4 *(continued)*

Stem modularity	Author	Year	No. of patients	Stem	Manufacturer	Bone loss[d]	FU years	PMA		HHS		KM[a]		Re-revision rate[a]
								Preop	Postop	Preop	Postop	Years	%	%
	Rodriguez *et al.* (32)	2009	102	MP	Waldemar Link	I–III[c]	3.3	–	–	36.0	84.0	–	–	5.0
	Kang *et al.* (33)	2008	39	ZMR	Zimmer	I–III[b]	2.0	–	–	–	72.3	–	–	0.0
	Koster *et al.* (34)	2008	73	Profemur-R	Wright Medical	I–IV	6.2	–	15.0	–	75.0	10.0	93.9	4.1
	Park *et al.* (35)	2007	62		Lima-Lto	I–IV	4.2	–	–	38.7	87.3	–	–	1.6
	McInnis *et al.* (36)	2006	70	PFM	Sulzer Orthopedics	I–III[f]	3.9	–	–	–	–	3.9	87.0[c]	4.3
	Schuh *et al.* (37)	2004	79	MRP Titan	PBC Mechanik	I–III	4.0	–	–	50.8	86.8	–	–	3.8
	Kwong *et al.* (38)	2003	143	MP	Waldemar Link	I–IV[g]	3.3	–	–	–	92.0	–	97.2	2.8

*, cemented; [a], stem revision for any reason; [b], stem revision for aseptic loosening; [c], worst-case; [d], Paprosky classification; [e], SOFCOT classification; [f], Pak classification; [g], Mallory classification; [h], Saleh classification. THA, total hip arthroplasty; FU, follow-up; PMA, Postel Merle d'Aubigné score; HHS, Harris Hip Score; KM, Kaplan-Meier.

series of revision THA in the literature are usually small (3,23,29,52). Second, though none of the patients showed or reported any adverse reactions or symptoms of metallosis, we did not test serum metal ion levels to demonstrate that these were within normal safe ranges. Further studies with longer follow-up and greater sample size will be needed to confirm our findings. Nevertheless, this study is the first to report clinical and radiographic outcomes of a unique modular stem design in revision THA.

Conclusions

The Optimal® uncemented modular neck stem seems to provide a satisfactory survival and satisfactory clinical outcomes at 5 years, with no noticeable adverse effects resulting from the additional modular junction. In this series, neck modularity enabled restoration of patient-specific femoral offset and limb length, though greater follow-up is required to confirm the long-term benefits and safety of this design concept.

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Footnote

Conflicts of Interest: Dr. Ouanezar received fees for consulting from Amplitude SAS during the conduct of the study; Dr. Pibarot received royalties from Amplitude SAS; Dr. Piton is a consultant for Amplitude SAS. The other authors have no conflicts of interest to declare.

Ethical Statement: All patients provided informed consent for the use of their data for research and publications and the study was performed in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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