

Outcomes of dual modular cementless femoral stems in revision hip arthroplasty

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Abstract

With an increasing number of primary hip replacements being performed every year, the burden of revision hip arthroplasty, for septic and aseptic loosening, recurrent dislocation or periprosthetic fracture, is also increasing. In recent years, different approaches to revising the femoral prosthesis have emerged; including both cemented and cementless techniques. With a stable cement mantle and good bone quality, or through the use of impaction bone grafting when bone stock is lacking, it is possible to re-cement a femoral prosthesis. Alternatively, a cementless modular femoral prosthesis may be used, providing the surgeon with further options for restoring leg length, hip offset, anteversion and stability. Studies evaluating the use of modular cementless prostheses have so far been limited to mid-term studies, with results comparable to primary hip arthroplasty. There are some concerns, however, regarding tribological complications such as stem fracture, corrosion, and failure, and long-term studies are required to further evaluate these concerns. This review outlines the current evidence for the use of both cemented and cementless modular femoral prostheses in the setting of revision hip arthroplasty. Results of prospective and retrospective studies will be outlined, along with results obtained from national joint registries.

Introduction

Total hip replacement remains a safe and effective means of providing pain relief to patients with a variety of underlying pathologies.¹ In addition to effective pain relief, total hip replacement also offers patients an improved quality of life through improved mobility and increased independence. Charnley's monoblock cemented femoral prosthesis and the original Exeter polished

cemented stem have both enjoyed great success as total hip prostheses. The survivorship of cemented Charnley hip replacements has been reported as 78% at 35 years,² while the long-term survivorship for the Exeter stem has been reported as being 93.5% at 33 years.³

However with success came failure and the need for revision surgery both on the acetabular and the femoral sides. Septic and aseptic loosening, recurrent dislocation, as well as periprosthetic fractures, demanded the development of additional techniques and prostheses for managing these new and challenging conditions. On the femoral side, initial femoral revision surgery was performed using cemented monoblock femoral stems. However, long-term outcomes and failure rates of these cemented stems were significantly inferior to primary hip replacement.⁴ The high early failure rate was noted mainly in patients younger than 55 years of age at the time of the primary surgery. Additionally, the use of primary monoblock stems in revision surgery made it difficult to accurately restore leg length, hip offset and stability. With advances in cementing techniques and the use of longer stems, the early failure rate of these revision cemented femoral stems did improve.⁵ The failure rate improved to 10% at 10 years and 15-20% at 15 years.⁶ This was in comparison to less than 5% at 10 years for primary cemented femoral stems. More recently, the use of impaction bone grafting,⁷ with newer cementing techniques and head/neck modularity has led to better outcomes with only 2% aseptic loosening at 10 years.⁸ This has become the benchmark against which comparisons are made with the development of newer implants and techniques. One such recent development in revision hip replacement has been the advent of cementless revision femoral stems. Early results were promising with failure rates of 4% at 4 years,⁹ however, subsidence and thigh pain were observed in association with these implants and a high re-revision rate in relation to these complications.¹⁰ This led to the inception of proximally coated modular revision stems, such as the S-ROM prosthesis (Joint Medical Products, Stamford, CT, USA), and extensively coated prostheses, such as the AML prosthesis (DePuy, Warsaw, IN, USA). The aim of these prostheses is to provide primary stability in order to prevent subsidence. The S-ROM has a re-revision rate of 1.5% at 5 years with subsidence still occurring in 4%.¹¹ The AML has a survival rate of 90.6% at 10 years with a re-revision rate of 5.7%.¹² Wagner *et al.*¹³ reported a good success rate with a modular long, fluted titanium-alloy textured stem, which achieved stability through diaphyseal fixation without porous coating. However, in situations where there is metaphyseal/diaphyseal bone loss these implants would have poor results due to the lack of bone stock.

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Key words: revision hip arthroplasty, cementless modular femoral stem.

Contributions: the authors contributed equally.

Conflict of interests: the authors declare no potential conflict of interests.

Received for publication: 18 December 2013.
Accepted for publication: 10 February 2014.

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Orthopedic Reviews 2014; 6:5247
doi:10.4081/or.2014.5247

Increasing modularity of femoral stems for revision surgery has been the next phase of innovation. Modularity is an advantage in revision hip replacement surgery for a number of reasons. Firstly, head-neck modularity facilitates the correction of leg length and offset, the use of larger femoral heads and alternative bearings or bearing exchange, with the ultimate goal of improving stability following revision surgery.¹⁴ It also allows temporary head removal in acetabular component exchange. It must be highlighted, however, that larger head and neck tapers (14/16) may be associated with increased dislocation rate.¹⁵ In addition, the large metal head bearings on femoral stems have shown catastrophic failure in association with certain implants.^{16,17} This has been linked to both trunnion wear and the metal on metal bearing. Another form of modularity is the formation of two junctions within the actual stem. This could be proximal modular or dual modular. In the proximal modular type, the distal junction is usually proximal to the femoral neck osteotomy. These are still mainly used in primary hip arthroplasty and in revision hip replacement with minimal bone loss. Dual modular femoral stems are defined as femoral stems with two or more junctions in which the distal junction is located in the metaphyseal/diaphyseal junction. They are used mainly in revision hip replacement associated with femoral bone loss.

Most recently, there has been an increased trend towards the use of dual modular cementless femoral stems in preference to cemented long stems, due to reported higher survival rates and better outcomes.^{18,19} These stems provide the ability to adjust femoral anteversion

sion, femoral offset, head size modularity and leg length.²⁰ This provides better stability and function in revision hip arthroplasty. These implants vary mainly in their distal stem configuration from extensively porous coated, grit-blasted, tapered with splines, smooth finished with splines, and slotted.²¹ However, these stems cannot be used in situations where there is complete loss of bone stock. There are many mid-term studies that show good outcomes with low failure rates and low re-revision rates.^{18,22,23}

The purpose of this review is to evaluate the literature regarding femoral stems in revision hip arthroplasty. The main objectives are analyzing long-term outcomes of established stems, new developments and their outcomes.

Review: methods

PubMed and the Cochrane Database of Systematic Reviews were used to search for the terms, *modular hip revision femoral stem*. Results were limited to the English language literature. The PubMed search to April 2013 produced 160 papers. The Cochrane Database search highlighted three results, two of which were not relevant to the current analysis. Abstracts were reviewed for all 160 papers and 59 papers were found to be relevant. Full papers were reviewed and key references were extracted from seminal reference papers. In addition, the results of national joint registries were included as they are the best representatives of long-term clinical outcomes across various population groups.

Current usage of modular implants as monitored by national joint registries

England, Wales and Northern Ireland

The use of cementless femoral prostheses in revision hip arthroplasty has markedly increased over recent years in England, Wales and Northern Ireland. In the 8th annual report of the National Joint Registry (NJR),¹⁶ there were 7852 revision hip procedures recorded between 2003-2010. 46% were revisions of both femoral and acetabular components while 17% were for the femoral component only. On the femoral side, a cementless femoral component was used in only 16% of revision cases compared to 48% where a cemented femoral component was used. In the most recent 10th annual report for the 2012 period, 8812 single-stage hip revision procedures were performed. Cemented and cementless femoral stems were used in 28% and 29% of cases, respectively.

43% did not require revision of the femoral stem. Unfortunately, the data as presented by these reports does not allow the identification of the brands of femoral stems used in revision surgery.

Sweden

In Sweden, during the 2009-2011 period, 5388 revision hip replacements were performed. This was an increase from 3243 revisions during the 1991-1993 period. Prior to 2010, there appeared to be a transition from the use of cemented femoral prostheses to cementless prostheses. In 2002, 81% of femoral revisions were performed using a cemented stem; while in 2010 there was relatively equal usage of cemented and cementless femoral stems for revision procedures. In the latest 2011 Swedish Hip Arthroplasty Register, 55% of femoral revisions made use of a cemented stem.

Weiss *et al.*²⁴ utilized the Swedish Register results to further evaluate the cementless modular Link MP system in comparison to cemented femoral stems in revision hip replacements. This was a study of 1885 revisions in which 812 were performed using cementless femoral stems and 1073 were performed using a long cemented femoral stem. At 3 years following surgery the survival of the cemented group was superior. The results showed that the cementless modular prosthesis had 1.9 relative risk of revision as compared to the cemented revision femoral stems. However, survival curves converged and became equivalent beyond the 3-year post-operative period.

Norway

The June 2010 report of the Norwegian Arthroplasty Register highlighted a changing trend in the use of cementless *versus* cemented femoral stems in revision total hip replacement.²⁵ In 1987, 75% of femoral revisions were performed using a cemented prosthesis. In 2009, only 23% of femoral revisions were performed using a cemented femoral stem, with the remaining 77% a cementless prosthesis. The most common revision femoral stem used in 2009 was a cementless single modular long stem (KAR, DePuy Warsaw, IN, USA). Cemented Exeter stems were next most commonly used, followed by a dual modular stem (Restoration, Stryker, Kalamazoo, MI, USA). The use of dual modular stems has quadrupled since 1987.

Australia, New Zealand and Canada

The 2013 National Joint Replacement Registry (Australian Orthopedic Association) annual report details the number of revisions performed without providing information on the type of prosthesis used in revision surgery.²⁶ The report

analyses in depth primary hip replacements with early or high failure rates but fails to focus on the current local trend of implant choice in revision hip surgery. Both the Canadian Joint Registry report and the New Zealand Joint Registry report suffered from the same lack of information regarding the type of femoral stems used in revision hip replacements.²⁷

Medium and long-term studies evaluating revision femoral stems

Cemented femoral stems

A number of high quality long-term studies have established cemented revision hip arthroplasty as a successful technique for revising a femoral component (Table 1).²⁸⁻³⁸ This has not always been the case, however, with early results showing high failure rates.³¹ The development of cementing techniques improved outcomes, however, survivorship was still inferior to primary total hip replacement. With the advent of impaction bone grafting, modularity, cement in cement revision, and the use of long stems, results are now comparable to primary total hip arthroplasty.^{8,28,32}

Holt *et al.*³⁹ have described 3 methods of femoral stem revision: i) femoral cement in cement revision with a stable cement bone interface, ii) femoral cement in cement for periprosthetic femoral fractures, and iii) cemented femoral revision with impaction bone grafting. The first method preserves the clinically and radiologically stable cement mantle by removing the old stem and cementing in a new Exeter stem. Duncan *et al.*²⁸ quoted a survival rate of 92% for the cement in cement revision with a stable bone cement interface. The second method relates to periprosthetic fractures with two scenarios. In the first scenario, both the stem and the cement mantle are unstable. Both are removed and replaced. In the second scenario, the cement mantle is deemed as stable and preserved with insertion of a new stem after reducing the periprosthetic fracture. This scenario is restricted to a limited number of cases or sometimes performed in the more unfit patients. The third method involves dealing with poor bone stock or bone loss through the use of impaction bone grafting. Halliday *et al.*³² reported a survivorship of 90.5% in the impaction bone grafting group. Wraight *et al.*³⁸ have replicated this with a 10-year survivorship of 92%. Ornstein *et al.*⁸ published the results of the Swedish hip registry. The paper looked at the results of 1305 revisions performed between 1989 and 2002 specifically looking at femoral impaction bone grafting. The results showed a 94% survivorship at 15 years follow up. All these established publications clearly highlight the

success rate of cemented revision femoral stems and sets the standard with which the newer dual modular cementless femoral stems are evaluated.

Cementless femoral stems and modularity

Similar to the evolution in cemented techniques, cementless femoral prostheses and procedures have also advanced in order to improve outcomes for patients undergoing revision hip replacement (Table 2).³⁵⁻⁴⁸ Early results for cementless femoral stems demonstrated high failure rates ranging from 4% to 9.5% within a follow up interval of 1 to 4 years.^{6,9,40} Trousdale and Morrey reported re-revision rates as high as 10%, with 37% showing subsidence of more than 2 mm with a mean average follow up of 4 years.⁴¹ Dorr *et al.*⁴² showed that with a collared cementless implant the re-revision rate improved from 50% to less than 1% and the subsidence rate was reduced from 50% to 0%. Further improvements were demonstrated by increasing primary stability and modularity of femoral implants. Proximally coated femoral stems, such as the S-ROM modular prosthesis (Joint Medical Products) yielded a 1.5% re-revision rate at 5 year follow-up.¹¹ Extensively coated modular stems such as the AML prosthesis (DePuy) and the Solution prosthesis (DePuy) had 5.7% and 6% re-revision rates at 8.4 and 5.8 years follow-up, respectively.^{12,43} Wagner presented excellent results for an innovative revision femoral stem.¹³ This was a long, fluted, titanium-alloy, and textured stem that relied on diaphyseal fixation. Wagner reported proximal bone ingrowth in relation to the stem. The advent of dual modular femoral implants for revision hip replacement was the next advance in design. Excellent results have been reported by a number of authors, however there are no Level I studies amongst these publications. Gross *et al.*⁴⁴ presented their results for the ZMR® porous stem (Zimmer, Warsaw, IN, USA) with midterm follow up from 5 to 10 years. This was a prospective study (Level IV evidence) of 72 femoral revisions using this stem only. The survival rate for the prosthesis was 93.8%, with revision for any reason as the endpoint. Mean follow up was 85 months. Holt *et al.*⁴⁹ published their results using the Restoration modular femoral stem (Stryker) in revision hip replacement. This was a prospective cohort study (Level IV evidence) of 46 patients showing a survival rate of 94%. This was a small study with a mean follow up of only 42 months. Cameron *et al.*²³ conducted a prospective study with 211 dual modular long stems. Mean follow up was 7 years. The revision rate was 1.4% in this group for aseptic loosening. Garbuz *et al.*⁵⁰ retrospec-

tively reviewed patients who underwent femoral revision between January 2000 and March 2006, comparing dual modular fluted tapered titanium stems with cylindrical non-modular chrome stems. This was a Level III study, which showed

that the dual modular group had better outcome scores, fewer complications and better femoral bone preservation or enhancement. However, survival analysis was not performed in this study.

Table 1. Cemented femoral stems in revision hip arthroplasty.

Authors	No. of hips	Follow-up (years)	Re-revision (%)	Loosening (%)
Rubash <i>et al.</i> ^{5*}	43	6.2 (mean)	4.0	11.0
Ornstein <i>et al.</i> ⁸ (Impaction bone grafting)	1305	5.0 (min)	-	0.9-1.0
Duncan <i>et al.</i> ²⁸ (Cement in cement)	136	8.0 (mean)	1.47	0.0
Pellicci <i>et al.</i> ³¹	99	8.1 (mean)	19.0	29.0
Halliday <i>et al.</i> ³² (Impaction bone grafting)	171	5.0 (min)	-	7.0
Kavanagh <i>et al.</i> ³³	210	10.0 (mean)	30.0	-
Estok <i>et al.</i> ^{34*}	38	11.7 (mean)	10.5	10.5
Katz <i>et al.</i> ³⁵	82	10 (min)	6.0	10.0
Izquierdo <i>et al.</i> ³⁶	112	6.5 (mean)	3.6	7.7
Collis <i>et al.</i> ^{37*}	110	4.6 (mean)	3.6	5.0
Wraighte <i>et al.</i> ³⁸ (Impaction bone grafting)	75	10.5 (mean)	-	13.0

*Second generation cementing technique.

Table 2. Monoblock and modular cementless femoral stems in revision hip arthroplasty.

Authors	No. of hips (years)	Follow-up (%)	Re-revision (%)	Loosening (%)
Engl <i>et al.</i> ⁹ (AML)	127	4 (mean)	-	4.0
McCarthy <i>et al.</i> ¹¹ (S-ROM)	133	5 (mean)	1.5	4
Lawrence <i>et al.</i> ¹² (AML)	174	8.4 (mean)	5.7	-
Palumbo <i>et al.</i> ²² (Restoration)	18	4.5 (mean)	6.0	-
Cameron <i>et al.</i> ²³ (S-ROM)	97	7.5 (mean)	3.0	0
Hedley <i>et al.</i> ⁴⁰ (PCA)	61	1 (min)	-	9.5
Trousdale and Morrey ⁴¹ (BIAS)	96	4.2 (mean)	10	37
Dorr <i>et al.</i> ^{41,42} (APR) (Collarless) (Collared)	100, 75	-	50, 1	50, 0
Paprosky <i>et al.</i> ^{43,44} (Solution)	311	5.8 (mean)	6.0	-
Gross <i>et al.</i> (ZMR)	72	7 (mean)	5.5	2.8
Kwong <i>et al.</i> ⁴⁵ (Link MP)	143	3.3 (mean)	2.8	0
Wirtz <i>et al.</i> ⁴⁶ (MRP-Titan)	142	2.3 (mean)	4.9	2.8
Wang <i>et al.</i> ⁴⁷ (Link MP)	58	4.3 (mean)	3.4	11
Jibodh <i>et al.</i> ⁴⁸ (ZMR)	54	7 (mean)	6.0	0

Implants: AML, DePuy, Warsaw, Ind; APR, Intermedics, Austin, Texas; BIAS, Zimmer, Warsaw, Ind; Link MP Link America, Denville, NJ; MRP-Titan, Peter Brehm, Weisendorf, Germany; Solution, DePuy; S-ROM, Joint Medical Products, Stamford, Conn; ZMR, Zimmer, Warsaw, Ind; Restoration, Stryker, NJ.

Palumbo *et al.*²² presented their intermediate results using the Stryker Restoration Cone Conical stem in cases with more severe femoral bone loss (Paprosky IIIB and IV). They achieved a 94% success rate with a mean follow up of 4.5 years. Jibodh *et al.*⁴⁸ recently presented 10-year results using the ZMR stem for femoral revision surgery. This is the longest follow-up period of any published study thus far. The 10-year survival rate, with revision for any reason and revision for femoral loosening as endpoints, were 94% and 100%, respectively. Bolognesi *et al.*⁵¹ has presented the only prospective randomized controlled trial using modular femoral stems, comparing hydroxyapatite coating with porous coating using the S-ROM stem. The survival rate for the implant was 94% at 4 years with hydroxyapatite-coated stems fairing significantly better in Paprosky III femora. There have been several complications associated with the use of the dual modular stems in revision hip replacement surgery. Richards *et al.*⁵⁰ reported the incidence of fractures occurring at the diaphyseal/metaphyseal junction of these modular stems. This was attributed to older designs, smaller stems and high body mass index.⁵² Sporer *et al.*^{53,54} reported a case of dissociation of a modular femoral neck trunnion. Atwood *et al.*⁵⁵ presented a case of corrosion-induced fracture of a dual modular stem. Skendzel *et al.*⁵⁶ reported on similar fractures that were attributed to long varus necks/titanium alloy couplings in modular stems used in patients with high body mass index. This has led to the adoption of cobalt chrome alloy adapters in some stem designs.

Corrosion may be associated with the use of single or dual modular femoral stems. Gilbert *et al.*⁵⁷ described the incidence of corrosion in association with mixed metal combinations. This may occur with the use of cobalt chrome heads on titanium-based stems through fretting corrosion especially in stems with long femoral necks. The debris and particles generated from the process of corrosion can lead to a local inflammatory reaction as well as the systemic release of metal ions.^{58,59} This may occur at either the head/neck interface or the metaphyseal/diaphyseal junction. Kretzer *et al.*⁶⁰ linked increased modularity, fretting corrosion and titanium ion release in vivo conditions. Fretting corrosion appears to be linked to failure at modular junctions in revision femoral stems.⁶¹

Financial considerations

It is generally accepted that the cost of a cementless femoral prosthesis is higher than a cemented femoral prosthesis.⁶² This is despite the utilisation of 3rd generation cementing techniques. Davies *et al.*⁶³ performed a review of the economic literature available for the large num-

ber of hip prostheses used in hip arthroplasty. Many of these prostheses did not possess an Orthopaedic Data Evaluation Panel (ODEP) 10A rating. There is a clear shortage of long-term survival data and more trials are required to assess the economic efficiency of the various hip implants available. This is also the case for revision femoral stems.

Conclusions

Cementless revision femoral stems have passed through several evolutionary design phases. Earlier implants were proximally coated monoblock stems with poor stability. With more extensive coating, modularity and diaphyseal fixation, results have improved. Cementless modular femoral stems can provide more anatomical options, allowing for correction of femoral offset, limb length and femoral anteversion. Newer dual modular *cone conical* type implants have shown excellent resilience in dealing with varying degrees of bone loss and good midterm results have been reported. However, modularity has yielded certain tribological complications. Dissociation, fatigue, fracture, corrosion, subsidence, and loosening are all potentially problematic. Also, the generation of metal ions at the multiple junctions remains of unknown significance. There is a need to provide further long-term survival and cost-benefit analysis. The use of cementless modular femoral stems should be confined to those patients with adequate bone stock, and so an important role for cemented femoral stems remains, with or without impaction bone grafting.

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