

Use of the Corail stem for revision total hip arthroplasty: evaluation of clinical outcomes and cost

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Background: With the growing number of total hip arthroplasty (THA) procedures performed, revision surgery is also proportionately increasing, resulting in greater health care expenditures. The purpose of this study was to assess clinical outcomes and cost when using a collared, fully hydroxyapatite-coated primary femoral stem for revision THA compared to commonly used revision femoral stems.

Methods: We retrospectively identified patients who underwent revision THA with a primary stem between 2011 and 2016 and matched them on demographic variables and reason for revision to a similar cohort who underwent revision THA. We extracted operative data and information on in-hospital resource use from the patients' charts to calculate average cost per procedure. Patient-reported outcomes were recorded preoperatively and 1 year postoperatively.

Results: We included 20 patients in our analysis, of whom 10 received a primary stem and 10, a typical revision stem. There were no significant between-group differences in mean Western Ontario and McMaster Universities Osteoarthritis Index score, Harris Hip Score, 12-Item Short Form Health Survey (SF-12) Mental Composite Scale score or Physical Composite Scale score at 1 year. Operative time was significantly shorter and total cost was significantly lower (mean difference -3707.64 , 95% confidence interval -5532.85 to -1882.43) with a primary stem than with other revision femoral stems.

Conclusion: We found similar clinical outcomes and significant institutional cost savings with a primary femoral stem in revision THA. This suggests a role for a primary femoral stem such as a collared, fully hydroxyapatite-coated stem for revision THA.

Contexte : Avec le nombre croissant d'interventions pour prothèse de hanche (PTH) effectuées, la chirurgie de révision est aussi proportionnellement en hausse, ce qui entraîne des coûts supérieurs pour le système de santé. Le but de cette étude était d'évaluer les résultats cliniques et le coût associés à l'emploi d'une prothèse fémorale primaire à collerette entièrement recouverte d'hydroxyapatite pour la révision de PTH, comparativement à d'autres prothèses d'usage courant utilisées pour les révisions.

Méthodes : Nous avons identifié rétrospectivement les patients ayant subi une révision de PTH avec une prothèse primaire entre 2011 et 2016 et nous les avons assortis selon les caractéristiques démographiques et le motif de la révision à une cohorte similaire soumise à une révision de PTH. Nous avons extrait les données sur l'opération et sur l'utilisation des ressources hospitalières à partir des dossiers des patients pour calculer le coût par intervention. Les résultats déclarés par les patients ont été notés avant l'intervention et 1 an après.

Résultats : Nous avons inclus 20 patients dans notre analyse, dont 10 ont reçu une prothèse primaire et 10, une révision de prothèse typique. On n'a noté aucune différence significative entre les groupes pour ce qui est du score WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) moyen pour l'arthrose, du score de Harris pour la hanche, ou des sous-échelles santé mentale ou santé physique à 1 an du questionnaire SF-12 (12-Item Short Form Health Survey). L'intervention a duré significativement moins longtemps et le coût a été significativement moindre (différence moyenne $-3707,64$, intervalle de confiance de 95 % $-5532,85$ à $-1882,43$) avec une prothèse primaire qu'avec les autres prothèses de révision.

Conclusion : Nous avons observé des résultats cliniques similaires et des économies significatives pour l'établissement avec la prothèse primaire utilisée pour la révision de PTH. Cela donne à penser que la prothèse fémorale primaire, par exemple, à collerette et entièrement recouverte d'hydroxyapatite, aurait un rôle à jouer pour la révision de PTH.

Although total hip arthroplasty (THA) is considered a widely successful operation, the increasing number of procedures has resulted in a growing number of revision operations.^{1,2} The most common causes for revision surgery include instability, mechanical loosening and infection.¹ Revision THA is associated with longer hospital stays and substantially higher costs.¹ In addition, such cases are challenging owing to structural bone loss, and various stem options, such as extensively porous, cemented, long proximally coated or modular stems are often required to obtain fixation.^{3,4}

In revision THA, it is critical to obtain good fixation between the implant–bone interface, which is often challenging as, in many cases, the femoral canal is smooth and sclerotic.⁵ The use of cementless femoral stems in revision THA is gaining popularity owing to the poor initial outcomes following use of cemented components.⁶ However, subsidence with proximally coated stems and higher revision rates have made surgeons turn to fully porous coated stems.^{4,6,7} The Corail femoral component (DePuy Synthes) is a cementless, tapered, fully hydroxyapatite-coated titanium stem with good clinical outcomes for both hip fracture management and THA for arthritis.^{8–12} The tapered design has been reported to avoid medullary canal blocking and distributes the stress, and the hydroxyapatite provides maximal osseointegration.¹¹ However, there are concerns regarding loose hydroxyapatite particles, which may lead to premature wear and osteolysis.¹² Although few studies have evaluated this stem in revision THA, results have been positive, with good long-term function.⁵

In contrast, modular stems are often used in revision settings as they can independently address distal fixation and bypass bone loss as well as optimize leg length, offset and stability proximally.¹³ However, this added ease with modularity is also associated with increased costs and adds a potential site of failure compared to monolithic stems.¹⁴ The results with modular stems have been positive in terms of patient-reported outcomes as well as complications and reoperation for mechanical failure.^{3,13,15,16}

The purpose of this study was to assess clinical outcomes and cost with the primary collared fully hydroxyapatite-coated Corail femoral stem for revision THA compared to commonly used revision femoral stems. We hypothesized that patient-reported outcomes at 1 year are similar to those with revision femoral stems. The substantial cost savings with the Corail stem could potentially justify the use of a primary femoral stem in a revision setting where proximal bone stock is deemed acceptable intraoperatively.

METHODS

We retrospectively identified patients who underwent revision THA with a Corail stem between 2011 and

2016. We compared this cohort with a group of patients who underwent revision THA with a revision stem, matched for age, body mass index and reason for revision based on an inclusive database search. We extracted operative data and information on in-hospital resource use from the patients' charts to calculate the average cost per procedure. Total procedure-related costs included implant cost and length of time in the operating room (from time in to time out). We obtained unit costs using administrative data from the case-costing department at our institution.

Patients prospectively completed several health-related quality-of-life instruments, including the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Harris Hip Score and 12-Item Short Form Health Survey (SF-12) Mental and Physical Composite Scales, at each visit with their surgeon. These instruments were also administered preoperatively and 1 year postoperatively. We recorded preoperative proximal femoral bone loss for the 2 groups and classified this using the Paprosky classification.¹⁷ Institutional ethics board approval was obtained for the study.

Statistical analysis

We used descriptive statistics to summarize the number of reoperations, operating room time, implant costs and quality of life for the 2 groups. We performed independent sample *t* tests to compare patient-reported outcomes between groups, with $p < 0.05$ set as the level of significance. We used nonparametric bootstrapping to compare differences in mean costs between groups. All costs are reported in 2017 Canadian dollars.

RESULTS

We included 20 patients in our analysis, of whom 10 received a primary collared Corail stem and 10 received a revision stem. Demographic characteristics, reason for revision and preoperative proximal femoral bone loss were similar between the 2 groups (Table 1). There were no significant differences in preoperative patient-reported outcomes (Table 1) ($p > 0.05$).

At 1 year postoperatively, there were no significant differences in mean WOMAC score ($p = 0.8$), mean Harris Hip Score ($p = 0.8$), mean SF-12 Mental Composite Scale score ($p = 0.9$) or mean SF-12 Physical Composite Scale score between the groups ($p = 0.3$) (Table 2).

There were no complications with the Corail stem. One patient underwent reoperation owing to persistent infection. Five complications occurred in the control group, 1 case each of pulmonary embolism, deep vein

Table 1. Baseline characteristics of patients who underwent revision total hip arthroplasty

| Characteristic | Mean \pm SD* | | p value |
|--|---|--|---------|
| | Corail group n = 10 | Control group n = 10 | |
| Age | 70 \pm 8.16 | 71 \pm 9.05 | 0.8 |
| Male/female ratio | 70/30 | 50/50 | |
| Body mass index | 31 \pm 3.5 | 31 \pm 6.05 | 1.00 |
| Reason for revision | Infection (3), aseptic loosening (3), pseudotumour (2), other (2) | Infection (4), aseptic loosening (3), pseudotumour (2), other (1) | |
| Type of stem | Corail | Restoration modular (Stryker) (6), AML monoblock (DePuy Synthes) (1), Reclaim modular (DePuy Synthes) (1), S-ROM modular (DePuy Synthes) (1), LPS universal fluted modular (DePuy Synthes) (1) | |
| Paprosky classification of preoperative femoral bone deficiency | Type I: 7 Type II: 2 Type IIIA: 1 | Type I: 6 Type II: 3 Type IIIA: 1 | |
| Harris Hip Score | 47.4 \pm 16.27 | 53.3 \pm 13.71 | 0.4 |
| 12-Item Short Form Health Survey Physical Composite Scale score | 26.6 \pm 3.08 | 32.7 \pm 8.48 | 0.1 |
| 12-Item Short Form Health Survey Mental Composite Scale score | 51.3 \pm 13.89 | 49.5 \pm 13.05 | 0.8 |
| Western Ontario and McMaster Universities Osteoarthritis Index score | 45.8 \pm 19.68 | 55.6 \pm 22.70 | 0.4 |

SD = standard deviation.
*Except where noted otherwise.

Table 2. Patient-reported outcomes at 1 year postoperatively

| Outcome | Mean score \pm SD | | |
|--|---------------------|------------------|--------------------------|
| | Corail group | Revision group | Mean difference (95% CI) |
| Harris Hip Score | 79.0 \pm 13.29 | 80.8 \pm 17.01 | 1.8 (-17.97 to 21.57) |
| 12-Item Short Form Health Survey Physical Composite Scale | 38.6 \pm 10.66 | 43.1 \pm 7.97 | 4.5 (-5.15 to 14.15) |
| 12-Item Short Form Health Survey Mental Composite Scale | 57.1 \pm 5.92 | 56.8 \pm 4.43 | -0.3 (-5.66 to 5.06) |
| Western Ontario and McMaster Universities Osteoarthritis Index | 79.2 \pm 16.18 | 81.0 \pm 12.76 | 1.8 (-13.17 to 16.77) |

CI = confidence interval; SD = standard deviation.

Table 3. Operating room and implant costs

| Variable | Mean \pm SD | | Mean difference (95% CI) |
|--------------------------|-----------------------|-------------------------|---------------------------------|
| | Corail group | Control group | |
| Operating room time, min | 171 \pm 25.14 | 217 \pm 45.09 | 46 (12.1 to 79.9) |
| Total cost, \$* | 5691.17 \pm 1006.10 | 10 721.75 \pm 3490.62 | -3707.64 (-5532.85 to -1882.43) |

CI = confidence interval; SD = standard deviation.
*Time in operating room and implant.

thrombosis, sciatic nerve palsy, dislocation and greater trochanter fracture. There were no reoperations in the control group.

The mean operative time was significantly shorter in the Corail group than in the control group (Table 3). Mean total operating room costs were significantly lower in the Corail group (mean difference -828.34 , 95% confidence interval -1420.67 to -270.56), as were mean implant costs (mean difference -2879.301 , 95% confidence interval -4293.82 to -1464.79).

DISCUSSION

In this retrospective study evaluating the clinical outcomes and costs for patients undergoing revision THA with a primary total hip femoral stem (Corail) compared to a matched control group of patients undergoing THA with a revision femoral stem, we found that patient-reported outcomes at 1 year postoperatively were not significantly different between the 2 groups. There were no complications in the Corail group, compared to 5 complications in the control group; complications in the latter group may be overrepresented owing to the small sample. Furthermore, operating room time and costs and implant costs also significantly favoured the Corail primary stem when used for revision THA. Taken together, the results suggest that there is a role for the use of a primary femoral stem such as the Corail in revision THA, especially in patients with minimal bone loss.

The Corail femoral stem is a tapered titanium stem with a proximal flared design allowing for a 3-dimensional metaphyseal fit.¹¹ Stability is achieved through initial press fit and secondarily via fixation through the bone-hydroxyapatite interface.^{11,12} The extensive hydroxyapatite coating increases biological fixation and allows for even stress distribution and good long-term survival.^{5,12} In a retrieval study of 165 patients, Coathup and colleagues¹⁸ found significantly more ingrowth and attachment to bone with the hydroxyapatite porous coating than with plasma spray or grit-blasted stems. Furthermore, the seal between the bone and the implant is purportedly strong with the Corail primary stem, which slows down wear particle migration, limiting osteolysis.^{12,18} This stem has been shown to have good results when used in the primary setting, with survivorship of 96.3% at 23 years.¹² Reikerås⁵ reported that, of 66 consecutive patients who underwent revision THA in which the Corail primary stem was used, only 1 required revision for mechanical failure. Although 8 hips that had a proximal fracture intraoperatively requiring wire fixation, long-term results were good up to 27 years.

In comparison, the matched cohort consisted of typical revision modular THA stems including the Restoration modular (Stryker), S-ROM (DePuy Synthes), Reclaim (DePuy Synthes) and LPS universal fluted mod-

ular (DePuy Synthes) in addition to an AML monoblock stem (DePuy Synthes). These stems enable the surgeon to engage the diaphysis to obtain axial and rotational stability distally.³ A distinct advantage of using a modular stem is obtaining a secure fit distally independent of the proximal body, which allows for optimization of limb length, stability and offset.³ This is especially important when there is a mismatch between bone loss proximally and distally.¹⁵ This was shown by Restrepo and colleagues,¹³ who used a Restoration modular stem in 118 patients; limb length was restored to within 5 mm in 75% of patients and offset to within 2 mm in 65% of patients. Dzaja and colleagues³ reported improvement in the WOMAC score and Harris Hip Score in 55 patients who underwent revision THA in which the Restoration modular stem was used, with 2 patients requiring revision owing to infection and subsidence. Similarly, in 161 revision THA procedures in which the Restoration modular stem was used, Riesgo and colleagues¹⁶ found an overall reoperation rate of 14.9% and an aseptic loosening rate of 2% with mean follow-up of 6.1 years. However, there are risks of junction failure and corrosion in addition to cost concerns when using modular femoral stems, especially in patients with minimal bone loss.¹⁴

Limitations

The limitations of this study include the small sample and the short follow-up period. Large prospective studies are warranted to support our results. However, the goal of this study was to compare early failures with a primary total hip femoral stem used in a revision setting and the cost differences as compared to revision femoral stems. Although it is recognized that a primary femoral component should be used only in specific circumstances, we mitigated this limitation by matching to revision cases with similar indications for revision surgery. In patients in whom the calcar is intact and there is minimal bone loss, with overall robust proximal femoral bone quality, a primary femoral stem can be appropriately used for revision THA.

CONCLUSION

Our results suggest a role for a primary femoral stem such as the Corail for revision THA. We found similar clinical outcomes and substantial institutional cost savings compared to a matched control group who received revision femoral stems. Therefore, taking into account patient factors including bone deficiency, a collared, fully hydroxyapatite-coated stem such as the Corail primary femoral stem can play a role in revision THA, with comparable early clinical results to those with other revision femoral stems.

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Contributors: T. Wood, L. Somerville, E. Vasarhelyi and B. Lanting designed the study. T. Wood, J. Marsh, L. Somerville and E. Vasarhelyi acquired the data, which all authors analyzed. T. Wood, M. Alzahrani and L. Somerville wrote the article, which all authors reviewed and approved for publication.

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