

Substantially higher prevalence of postoperative periprosthetic fractures in octogenarians with hip fractures operated with a cemented, polished tapered stem rather than an anatomic stem

A prospective cohort study involving 979 hips

Sebastian MUKKA¹, Carl MELLNER¹, Björn KNUTSSON^{1,2}, Arkan SAYED-NOOR¹, and Olof SKÖLDENBERG³

¹ Department of Orthopedics, Sundsvall Hospital, Sundsvall, and Department of Surgical and Perioperative Sciences, Umeå University, Umeå;

² Department of Surgical Sciences, Section of Orthopedics, Uppsala University, Uppsala; ³ Department of Orthopedics, Danderyd Hospital and Karolinska Institutet, Stockholm, and Department of Clinical Sciences, Danderyd Hospital, Stockholm, Sweden.

Correspondence: sebastian.mukka@gmail.com

Submitted 2015-11-12. Accepted 2016-02-08.

Background and purpose — Recent studies have demonstrated a high incidence of postoperative periprosthetic femoral fracture (PPF) in elderly patients treated with 2 commonly used cemented, polished tapered stems. We compared the prevalence and incidence rate of PPF in a consecutive cohort of octogenarians with femoral neck fractures (FNFs) treated with either a collarless, polished tapered (CPT) stem or an anatomic matte stem (Lubinus SP2).

Patients and methods — In a multicenter, prospective cohort study, we included 979 hips in patients aged 80 years and above (72% females, median age 86 (80–102) years) with a femoral neck fracture as indication for surgery. 69% of the patients were classified as ASA class 3 or 4. Hip-related complications and repeat surgery were assessed at a median follow-up of 20 (0–24) months postoperatively.

Results — 22 hips (2.2%) sustained a PPF at a median of 7 (0–22) months postoperatively; 14 (64%) were Vancouver B2 fractures. 7 of the 22 surgically treated fractures required revision surgery, mainly due to deep infection. The cumulative incidence of PPFs was 3.8% in the CPT group, as compared with 0.2% in the SP2 group ($p < 0.001$). The risk ratio (RR) was 16 (95% CI: 2–120) using the SP2 group as denominator.

Interpretation — The CPT stem was associated with a higher risk of PPF than the SP2 stem. We suggest that the tapered CPT stem should not be used for the treatment of femoral neck fractures in patients over 80 years.

patients (Lindahl et al. 2007, Shields et al. 2014). The surgical treatment of PPF can be technically demanding and plagued with a high frequency of complications due to deep infection, dislocation, and intraoperative fractures (Lindahl et al. 2006b). Under-reporting of reoperations for PPFs has to some extent undermined the integrity of the Swedish Hip Arthroplasty Register (SHAR). This is because the SHAR does not capture patients treated with open reduction and internal fixation without exchange of the implant (Garellick et al. 2014).

The 2 most commonly used cemented implants in Sweden are the polished, tapered Exeter stem and the matte anatomic SP2 stem (Garellick et al. 2014). The CPT stem (Zimmer Inc., Warsaw, IN) is similar to the Exeter stem, as both are collarless, polished, and tapered femoral stems (Yates et al. 2008). The CPT stem is the third most commonly used femoral component in Sweden for fracture patients (Garellick et al. 2014). Previous reports have shown good long-term results in primary arthroplasty for osteoarthritis (Yates et al. 2008, Burston et al. 2012). On the other hand, recent studies have identified a high incidence of PPF associated with the CPT and Exeter stems in elderly patients with femoral neck fractures (Inngul and Enocson 2015, Brodén et al. 2015, Raut and Parker 2015). The Lubinus SP2 stem (Waldemar Link, Hamburg, Germany) is the most commonly used femoral component in Sweden (Garellick et al. 2014).

To our knowledge, no earlier prospective cohort studies have compared these 2 types of femoral stems regarding the risk of PPF in octogenarians with hip fractures. We therefore investigated the risk of PPF according to the type of stem.

Postoperative periprosthetic fracture (PPF) is a severe complication of hip arthroplasty, especially in elderly and fragile

Patients and methods

Study setting

This observational prospective cohort study was performed between 2009 and 2015 at 2 Swedish hospitals: the orthopedics department of Danderyd Hospital in Stockholm and the orthopedics department of Sundsvall Hospital, Sundsvall. Danderyd Hospital is a university hospital affiliated to the Karolinska Institute, and provides medical care to a catchment area with approximately 500,000 inhabitants. Sundsvall Hospital is an emergency hospital affiliated to Umeå University, and provides medical care to a catchment area of approximately 160,000 inhabitants.

Patients

We included all patients aged 80 years and above who were operated on between September 2009 and April 2015 with a primary hip arthroplasty for an acute displaced FNF. Patients were treated either with a cemented CPT stem or with a cemented SP2 stem.

Data collection

Using the unique Swedish personal identification number, we collected data prospectively throughout the study period by a combination of searching in our in-hospital surgical and medical database and follow-up visits. A digital case report form was used throughout the study.

All the patients were followed up until October 2015 or until death (from a search in the medical database).

The median follow-up time was 20 (0–24) months, with no loss to follow-up. We collected patient data including age, sex, comorbidities registered at primary surgery, ASA score, type of arthroplasty (total hip arthroplasty or hemiarthroplasty), surgical approach (direct lateral or posterolateral), and all complications including closed reduction of dislocated hips and any subsequent open surgery including revision of implants.

For patients with a PPF, the radiographs were classified (Vancouver) by 1 of the authors (OS—a senior consultant specialized in hip revision surgery). This type of classification has been shown to be valid and reliable by Brady et al. (2000), in a European setting.

Implant and surgery

At both institutions, a cemented hemiarthroplasty (HA) or a total hip arthroplasty (THA) is the standard treatment for a displaced femoral neck fracture in all patients who are medically fit for arthroplasty surgery. At Danderyd Hospital, the CPT stem (Zimmer Inc., Warsaw, IN) was standard treatment between 2009 and 2013, and then the SP2 stem was used. The CPT stem (130 mm) is a collarless, polished and tapered femoral stem in chrome cobalt alloy. The stem is double-tapered and has a rectangular proximal geometry. A modular 32-mm cobalt-chrome femoral head was used in all THA patients

together with a cemented highly cross-linked polyethylene acetabular component (a ZCA cup from Zimmer; a Marathon cup from DePuy; or a Lubinus from Waldemar Link, Hamburg, Germany). A modular unipolar head (Versys Endo; Zimmer) was used for patients operated with a CPT stem. At Sundsvall Hospital, the SP2 stem was used throughout the study period. The Lubinus SP2 (150 mm) is an anatomic cobalt-chromium stem (Waldemar Link). A modular 32-mm cobalt-chrome femoral head was used for THA and either a unipolar head (Unipolar; Waldemar Link) or a bipolar head (Vario cup; Waldemar Link) was used for hemiarthroplasty.

Patients were operated either with a direct lateral Gammmer approach or a posterolateral approach depending on surgeon preference. The same bone cement was used for all patients (Optipac; Biomet, Sweden). Prophylactic antibiotics (cloxacillin; Meda, Solna, Sweden) were administered 30 min preoperatively and 2 more times over 24 h postoperatively. Low-molecular-weight heparin was administered for 10–30 days postoperatively. Patients were mobilized according to a standard physiotherapeutic program, and full weight bearing with the use of crutches was encouraged. Patients who were operated with a posterolateral approach were instructed to minimize flexion in combination with adduction and internal rotation for the first 3 months. Primary surgery was performed either by a consultant orthopedic surgeon or by a registrar assisted by a consultant.

Statistics

The cumulative incidences of PPF in the 2 study groups were compared using risk ratio (RR) with 95% confidence interval (95% CI). Due to slightly different follow-up periods in the CPT group and the SP2 group, we performed a sensitivity analysis; a Poisson regression model was used to calculate the incidence rate ratio (IRR). Statistical analysis was performed using SPSS Statistics software version 22.0.

Ethics and registration

The study was conducted in accordance with the ethical principles of the Helsinki Declaration and was approved by the Ethics Committee of Umeå University (entry number 205/289-31). The study was registered at ClinicalTrials.gov (identifier: NCT02591342).

Results

Patients

555 hip arthroplasties were performed with the CPT stem and 424 were performed with the SP2 stem (Table 1). The median age in the cohort was 86 (80–102 years). The direct lateral approach was more often used in the CPT group; otherwise, the groups were similar (Table 1). The median follow-up time was 20 (0–24 months). Mortality was similar in patients who sustained a PPF and those who did not ($p = 0.4$, log rank test).

Table 1. Patient characteristics. Values are n (%)

	CPT (n = 555)	SP 2 (n = 424)
Sex		
Male	157 (28)	127 (30)
Female	398 (72)	297 (70)
Age (range), median	86 (80–102)	86 (80–102)
ASA category		
1–2	128 (23)	169 (39)
3–4	424 (77)	249 (61)
Hospital		
Danderyd	570 (100)	142 (34)
Sundsvall	0 (0)	282 (66)
Type of arthroplasty		
THA	58 (10)	23 (5)
HA	512 (90)	415 (95)
Surgical approach		
Posterolateral	14 (3)	156 (36)
Direct lateral	552 (97)	267 (63)

Table 2. Periprosthetic fractures, surgical treatment, and surgical outcome. Values are n

Vancouver classification	CPT	SP2
A	0	0
B1	3	0
B2	14	0
B3	2	0
C	2	1
Total	21	1
Surgical treatment		
Open reduction and internal fixation	7 ^a	
Stem revision	15 ^b	
Surgical outcome		
Deep infection reoperation	5	
Dislocation reoperation	1	
Refracture	1	
Healing without complication	15	

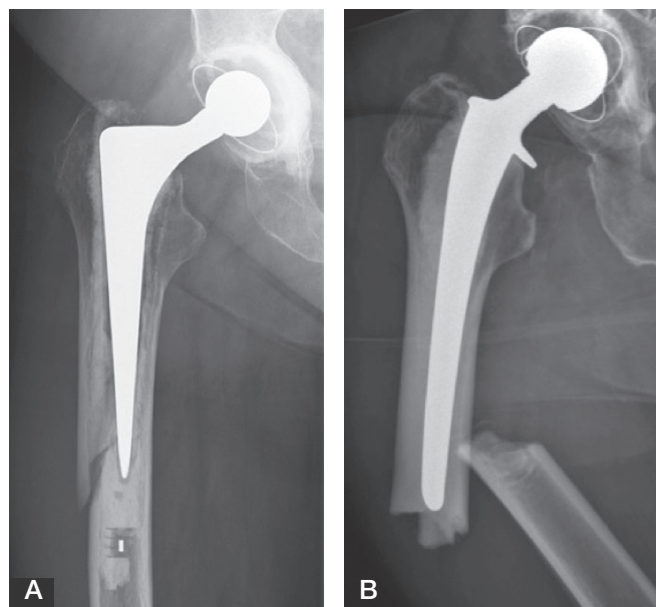
^a All type C and B1 fractures were treated with ORIF. In all cases, a femoral locking plate or cerclage wire was used.

^b B2 and B3 fractures were treated with stem revision, except 1 case where cerclage wires were used. In all stem revisions, the newly implanted femoral stem was reinforced with a femoral locking plate and/or cerclage wires.

Outcome

22 PPFs (2.2%) occurred during the study period (2009 through 2015). The fractures occurred early, at median 5 (0–22 months) after primary surgery. None of these PPFs were intraoperative.

The cumulative incidence of PPFs was 3.8% in the CPT group and 0.2% in the SP2 group ($p < 0.001$). The RR was 16 (95% CI: 2–120; $p < 0.001$) using the SP2 group as denominator. The sensitivity analysis with Poisson regression model gave similar results (IRR = 12, 95% CI: 2–91; $p = 0.01$).



2 periprosthetic femoral fractures. A. Vancouver B2 fracture around a CPT stem. B. Vancouver C fracture below a Lubinus stem.

The most common complication in the whole cohort was revision surgery due to periprosthetic joint infection (3%), followed by dislocation (2%) and PPF (2%). In the CPT group, PPF was the most common complication (4%) followed by dislocation (2%) and periprosthetic joint infection (2%). In the SP2 group, periprosthetic joint infection was the most common reason for revision surgery (4%), followed by dislocation (3%) and PPF (0.2%).

Periprosthetic fracture

Most of the periprosthetic fracture types (14 of 22) were Vancouver type-B2 fractures (Table 2 and Figure). None of the hips had any radiographic signs of loosening of the stem or periprosthetic osteolysis before fracture. Of the 22 PPFs, 7 required additional revision surgery, mainly due to periprosthetic joint infection (Table 2).

Discussion

In this prospective cohort study, based on a large cohort of octogenarians treated with hip arthroplasty for a femoral neck fracture, the CPT stem resulted in a high incidence of PPF relative to the Lubinus SP2 anatomic stem.

Osteopenia and age over 80 years in combination with femoral neck fracture as indication for primary surgery has been linked to an increased incidence of PPF and predisposition to Vancouver B2 and complex C PPF (Sarvilinna et al. 2004, Franklin and Malchau 2007, Cook et al. 2008, Brodén et al. 2015). We found a high incidence of early PPFs in those patients who received a CPT stem. PPF was the most common

reason for early reoperation with the CPT stem, which contrasts with data from the SHAR (Garellick et al. 2014). However, the SHAR does not capture patients treated with open reduction and internal fixation without exchange of the implant (Thien et al. 2014). The annual report published in 2015 included an analysis regarding the under-reporting, and 24% of the PPFs were not reported (Garellick et al. 2015).

We did not use a regression analysis to adjust for confounders, due to the low number of PPFs in the SP2 group. In the present study, one third of the PPFs were treated with osteosynthesis without exchange of prosthetic components. A registry-based study from the Nordic Arthroplasty Register Association Database found that the cemented Exeter stem, which resembles the CPT stem, was associated with a 5-fold increased risk of PPF relative to the SP2 stem (Thien et al. 2014).

There are diverging results reported regarding the risk of PPF in patients treated with hip arthroplasty for FNF. Philipps et al. (2013) reported an incidence of 1.7% in a large series of uncemented Austin-Moore prostheses and several cemented stems. Smaller studies have found varying rates of PPF—between 0% and 4% (Leonardsson et al. 2010, Hedbeck et al. 2011, Chammout et al. 2012, Johansson 2014). In accordance with our findings, recent studies have shown an association between cemented, polished tapered stems and a high risk of PPF (Inngul and Enocson 2015, Brodén et al. 2015). The follow-up times, types of components, type(s) of fixation, age, and selection of patients varied between the different studies.

In our previous report (Brodén et al. 2015), we suggested that the polished tapered stem, which is designed to subside in the cement mantle, also appears to act as a stress riser, splitting the femur after a hip contusion, resulting in a complex PPF. Straight, tapered stems appear to be more frequently malaligned with endosteal contact of the tip in FNF patients (Hank et al. 2010, Macpherson et al. 2010). One could speculate about the importance of stem size and the risk of PPF in polished tapered stems. A larger stem size could reduce the cement mantle and thus increase the risk of endosteal contact of the tip of the prosthesis, which could in turn increase the stress arising after a hip contusion. A smaller stem size may increase the cement mantle, and thus counteract the stress arising as mentioned above. However, biomechanical testing has indicated that larger stem sizes and longer stems increase the resistance to torque forces (Bishop et al. 2010, Morishima et al. 2014, Ginsel et al. 2015). These suggestions remain to be investigated further regarding specific stems. The SP2 stem is designed for a more distal femoral neck osteotomy than the CPT stem. The distal osteotomy visualizes the femoral canal, and the anatomically shaped design might facilitate a better alignment. The anatomic shape, the more distal anchoring of the stem, and the possibly favorable stem positioning of the SP2 stem might be the reasons for the lower risk of PPF in this fragile and high-risk population. A recently published retrospective study by Raut and Parker (2015) found a PPF

incidence of 1.0% for the Exeter Trauma stem. The patients in our study were older, and the high incidence of osteoporosis in Sweden could increase the risk of PPF.

It has been suggested that the surgical approach could alter the incidence of PPF. This could be linked to the proposed higher incidence of anteroposterior malalignment in the sagittal plane (Garellick et al. 1999, Lindahl et al. 2006a). In a previous study from our department, which included a larger number of patients with CPT stems, we did not find any statistically significant association between the Gummer approach and the risk of PPF (Brodén et al. 2015). Due to the fact that the Gummer approach was used in most of the patients in the CPT group and the number of PPFs was relatively low, it is difficult to assess the influence of surgical approach.

The strengths of the present study include its prospective design, with a complete follow-up. The weakness is the relatively short follow-up time. However, in this group of patients the short-term results are most interesting—due to the short lifespan remaining. In addition, most of the fractures in our study were found within 1 year after the index surgical procedure. Nevertheless, longer follow-up would be needed to determine any long-term differences between the study groups. The relatively small sample size for studying this type of complication is a limitation that was counteracted by selection of patients at the highest risk of sustaining a PPF, and it therefore justifies the comparison between the 2 types of femoral components.

In summary, in octogenarian patients with high comorbidity and osteoporosis, the cemented, straight, polished tapered stem was found to be associated with a high rate of early PPFs relative to the SP2 stem. We suggest that the tapered CPT stem should not be used in the treatment of femoral neck fracture in patients over 80 years.

SM initiated the study, operated patients, collected data, performed statistical analysis, and wrote the manuscript. CM collected data and wrote the manuscript. ASN operated patients and wrote the manuscript. BK operated patients, performed statistical analysis, and wrote the manuscript. OS operated patients, collected data, and wrote the manuscript.

No competing interests declared.

Bishop N E, Burton A, Maheson M, Morlock M M. Biomechanics of short hip endoprostheses—the risk of bone failure increases with decreasing implant size. *Clin Biomech (Bristol, Avon)* 2010; 25 (7): 666-74.

Brady O H, Garbuz D S, Masri B A, Duncan C P. The reliability and validity of the Vancouver classification of femoral fractures after hip replacement. *J Arthroplasty* 2000; 15 (1): 59-62.

Brodén C, Mukka S, Muren O, Eisler T, Boden H, Stark A, et al. High risk of early periprosthetic fractures after primary hip arthroplasty in elderly patients using a cemented, tapered, polished stem. *Acta Orthop* 2015; 86 (2): 169-74.

Burston B J, Barnett A J, Amirfeyz R, Yates P J, Bannister G C. Clinical and radiological results of the collarless polished tapered stem at 15 years follow-up. *J Bone Joint Surg Br* 2012; 94 (7): 889-94.

- Chammout GK, Mukka SS, Carlsson T, Neander GF, Stark AW, Skoldenberg OG. Total hip replacement versus open reduction and internal fixation of displaced femoral neck fractures: a randomized long-term follow-up study. *J Bone Joint Surg Am* 2012 Nov 7;94(21):1921-8.
- Cook R E, Jenkins P J, Walmsley P J, Patton J T, Robinson C M. Risk factors for periprosthetic fractures of the hip: a survivorship analysis. *Clin Orthop Relat Res* 2008; 466 (7): 1652-6.
- Franklin J, Malchau H. Risk factors for periprosthetic femoral fracture. *Injury* 2007; 38 (6): 655-60.
- Garellick G, Malchau H, Herberts P. The Charnley versus the Spectron hip prosthesis: clinical evaluation of a randomized, prospective study of 2 different hip implants. *J Arthroplasty* 1999; 14 (4): 407-13.
- Garellick G K J, Lindahl H, Malchau H, Rogmark C, Rolfson O. Annual report from the Swedish Hip Arthroplasty Register. 2013. 2014; 196. <http://www.shpr.se/sv/Publications/DocumentsReports.aspx>. Accessed 3 November 2015.
- Garellick G K J, Lindahl H, Malchau H, Rogmark C, Rolfson O. Annual report from the Swedish Hip Arthroplasty Register. 2014. 2015. <http://www.shpr.se/sv/Publications/DocumentsReports.aspx>. Accessed 3 November 2015.
- Ginsel B L, Morishima T, Wilson L J, Whitehouse S L, Crawford R W. Can larger-bodied cemented femoral components reduce periprosthetic fractures? A biomechanical study. *Arch Orthop Trauma Surg*. 2015; 135(4): 517-22.
- Hank C, Schneider M, Achary C S, Smith L, Breusch S J. Anatomic stem design reduces risk of thin cement mantles in primary hip replacement. *Arch Orthop Trauma Surg* 2010; 130 (1): 17-22
- Hedbeck C J, Enocson A, Lapidus G, Blomfeldt R, Tornkvist H, Ponzer S, Tidermark J. Comparison of bipolar hemiarthroplasty with total hip arthroplasty for displaced femoral neck fractures: a concise four-year follow-up of a randomized trial. *J Bone Joint Surg Am* 2011; 93: 445-50.
- Inngul C, Enocson A. Postoperative periprosthetic fractures in patients with an Exeter stem due to a femoral neck fracture: cumulative incidence and surgical outcome. *Int Orthop* 2015; 39(9): 1683-8.
- Johansson T. Internal fixation compared with total hip replacement for displaced femoral neck fractures: a minimum fifteen-year follow-up study of a previously reported randomized trial. *J Bone Joint Surg Am* 2014; 96: e46.
- Leonardsson O, Sernbo I, Carlsson A, Akesson K, Rogmark C. Long-term follow-up of replacement compared with internal fixation for displaced femoral neck fractures: results at ten years in a randomised study of 450 patients. *J Bone Joint Surg Br* 2010; 92(3): 406-12. Erratum in: *J Bone Joint Surg Br*.
- Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures classification and demographics of 1049 periprosthetic femoral fractures from the Swedish National Hip Arthroplasty Register. *J Arthroplasty* 2005; 20 (7): 857-65.
- Lindahl H, Garellick G, Regner H, Herberts P, Malchau H. Three hundred and twenty-one periprosthetic femoral fractures. *J Bone Joint Surg Am* 2006a; 88 (6): 1215-22.
- Lindahl H, Malchau H, Oden A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. *J Bone Joint Surg Br* 2006b; 88 (1): 26-30.
- Lindahl H, Oden A, Garellick G, Malchau H. The excess mortality due to periprosthetic femur fracture. A study from the Swedish national hip arthroplasty register. *Bone* 2007; 40 (5): 1294-8.
- Macpherson G J, Hank C, Schneider M, Trayner M, Elton R, Howie C R, et al. The posterior approach reduces the risk of thin cement mantles with a straight femoral stem design. *Acta Orthop* 2010; 81 (3): 292-5
- Morishima T, Ginsel B L, Choy G G, Wilson L J, Whitehouse S L, Crawford R W. Periprosthetic fracture torque for short versus standard cemented hip stems: an experimental in vitro study. *J Arthroplasty* 2014; 29(5): 1067-71.
- Phillips J R, Moran C G, Manktelow A R. Periprosthetic fractures around hemiarthroplasty performed for hip fracture. *Injury* 2013; 44(6): 757-62.
- Raut S, Parker M J. Medium to long term follow up of a consecutive series of 604 Exeter Trauma Stem Hemiarthroplasties (ETS) for the treatment of displaced intracapsular femoral neck fractures. *Injury* 2015 Nov 10. pii: S0020-1383(15)00696-8. doi: 10.1016/j.injury.2015.10.077. [Epub ahead of print].
- Sarvilinna R, Huhtala H S, Sovelius R T, Halonen P J, Nevalainen J K, Pajamaki K J. Factors predisposing to periprosthetic fracture after hip arthroplasty: a case (n = 31)-control study. *Acta Orthop Scand* 2004; 75 (1): 16-20.
- Shields E, Behrend C, Bair J, Cram P, Kates S. Mortality and financial burden of periprosthetic fractures of the femur. *Geriatr Orthop Surg Rehabil* 2014; 5 (4): 147-53.
- Thien T M, Chatziagorou G, Garellick G, Furnes O, Havelin L I, Makela K, et al. Periprosthetic femoral fracture within two years after total hip replacement: analysis of 437,629 operations in the nordic arthroplasty register association database. *J Bone Joint Surg Am* 2014; 96 (19): e167.
- Yates P J, Burston B J, Whitley E, Bannister G C. Collarless polished tapered stem: clinical and radiological results at a minimum of ten years' follow-up. *J Bone Joint Surg Br* 2008; 90 (1): 16-22.