

Blood-pressure changes and outcomes associated with cemented bipolar hemiarthroplasty for displaced femoral-neck fractures

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Abstract

Background The purpose of this retrospective cohort study was to investigate the cementing effects on intraoperative blood pressure and the clinical and radiographic outcomes in elderly patients with femoral-neck fracture undergoing bipolar hemiarthroplasty using a polished, tapered stem.

Methods This retrospective cohort study included 38 patients with acute displaced femoral-neck fractures (mean age, 76.2 years; mean follow-up, 21.4 months (68 % follow-up rate)). **Results** Intraoperative systolic blood pressure decreased significantly, both during cementing (109.1 mmHg) and after stem insertion (101.6 mmHg), compared with the level before rasping (122.2 mmHg; $p=0.0036$ and $p=0.0001$, respectively). Diastolic blood pressure decreased significantly after stem insertion (57.9 mmHg versus 67.3 mmHg before rasping; $p=0.003$). Hypoxia did not occur. Nineteen patients were Donaldson's grade 1, 16 were grade 2, and none were grade 3. Twenty-three patients (74 %) maintained their preoperative activity level; 15 (26 %) worsened after surgery. Stem subsidence significantly increased over time: 0.32 mm at 6 months, 0.53 mm at 1 year, 0.91 mm at 2 years, 1.08 mm at 3 years, and 1.13 mm at 4 years.

Conclusions Cemented bipolar hemiarthroplasty for displaced femoral-neck fracture in elderly patients leads to

hypotension, unchanged arterial oxygen saturation, favorable clinical outcomes, and acceptable stem subsidence.

Keywords Hypotension · Cemented bipolar hemiarthroplasty · Femoral-neck fracture

Abbreviations

SaO ₂	Arterial oxygen saturation
SBP	Systolic blood pressure
ANOVA	Analysis of variance
SPSS	Statistical Package for the Social Sciences
PaO ₂	Partial pressure of oxygen

Introduction

There has been a drastic increase in the number of Japanese patients with hip fracture over the course of the last decade, from 36 000 in 1998 to 68 000 in 2008 [1]. Hemiarthroplasty has a better functional outcome and fewer complications than internal fixation for the treatment of displaced femoral-neck fractures in elderly patients [2–4]. There are many different prostheses available for hemiarthroplasty, but the optimal technique remains controversial [4]. For example, it is unclear whether cemented or uncemented implants are preferable in this patient population. Several clinical trials and systematic reviews have indicated favorable clinical outcomes with cemented implants: reduced hip pain, faster recovery from disability, and shorter hospital stays [4–7]. Taylor et al. [6] reported that cemented hemiarthroplasty has a significantly lower rate of implant-related complications, in both the intraoperative and postoperative periods.

However, because of concerns about the physiological effect of cement on the cardiopulmonary system [8, 9], the difficulty

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of modern cementing techniques and the extended surgical time involved with cemented implants, uncemented bipolar hemiarthroplasty is likely to be selected in some trauma centers in Japan. Little is known about changes in blood pressure induced by the cement during bipolar hemiarthroplasty; previous studies have reported both hypotension and hypertension during cementing arthroplasty [10–13]. Furthermore, there have been few reports on radiographic follow-up assessment of cemented bipolar hemiarthroplasty.

The purpose of this study was to clarify the clinical outcomes, the radiographic outcomes, and the cementing effects on intraoperative blood pressure associated with cemented bipolar hemiarthroplasty in elderly patients with displaced femoral-neck fractures.

Patients and methods

The inclusion criteria of this study were patients with acute displaced femoral-neck fractures (Garden stage III or IV) treated between April 2008 and January 2013. A total of 64 patients (64 hips) underwent cemented bipolar hemiarthroplasty using a polished, tapered stem via a lateral approach at a single institution. We excluded six patients who required a different implant and two who required a different surgical technique. Other exclusion criteria included a previous fracture of the same hip, a pathological fracture, or a high risk of perioperative mortality as assessed by the anesthesiologist and operating physician (no patients were excluded based on these criteria). A total of 18 patients were excluded for not having more than 3 months of documented follow-up.

As a general rule, patients were treated with cemented bipolar hemiarthroplasty using a polished, tapered stem: the Exeter stem and Centrax head (Stryker Howmedica Osteonics, Mahwah, New Jersey); the Hardinge approach was employed with the patient in the lateral decubitus position. Orthopedic residents performed all surgery supervised by the senior author, a hip specialist. After rasping the canal, the stem was inserted with canal-filling (tight-fit) implantation [14–16]. The third-generation cementing technique was applied, using 80 g of Surgical Simplex P bone cement (Stryker Howmedica Osteonics, Mahwah, New Jersey) mixed with 2 g of cephazolin immediately before cementing. One gram of prophylactic cephazolin was administered preoperatively, followed by another dose at 3 and 6 h postoperatively. For prevention of deep venous thromboembolism, patients were encouraged to mobilize with full weight bearing, as tolerated, on postoperative day 1.

The clinical outcome was defined as the activity change from the preoperative level to the postoperative level and was classified into four grades based on walking ability: grade 1, able to use public transportation; grade 2, able to ambulate around the immediate neighborhood; grade 3, able to be active only indoors; grade 4, bedridden [17].

Noninvasive blood pressure measurements were taken from reviewing the anesthetic charts every 5 min during surgery in order to determine changes in intraoperative blood pressure and arterial oxygen saturation (SaO₂) before rasping, during cementing and after stem insertion. These charts have these particular time points marked on them routinely. All the surgeries were performed under general anesthesia. The Donaldson grade was used to evaluate for bone cement implantation syndrome [18]: grade 1, moderate hypoxia (SaO₂ <94 %) or hypotension (decrease in systolic blood pressure (SBP) >20 %); grade 2, severe hypoxia (SaO₂ <88 %) or hypotension (decrease in SBP >40 %) or unexpected loss of consciousness; grade 3, cardiovascular collapse requiring cardiopulmonary resuscitation. Peri- and postoperative complications such as infection, dislocation, and fracture were assessed.

Radiographic examination was performed to investigate cementing grade, stem subsidence, and stem loosening (radiolucent lines and osteolysis) by the first author. The cementing grade was determined at 1 week using Mulroy and Harris' classification [19] on an anteroposterior radiograph of the pelvis. Stem subsidence around the stem-cement interface was assessed by measuring the vertical dimension of radiolucency, in a craniolateral direction, to the shoulder of the stem in zone 1 [20], as described by Fowler et al. [21]. If this was impossible for technical reasons, such as when the shoulder of the stem projected above the most proximal area of cement, subsidence was assessed using the change in the distance between the tip of the stem and the inferior pole of the centraliser, comparing the immediate postoperative and most recent radiographs [22]. Stem subsidence was evaluated at 6 months, 1 year, 2 years, 3 years, and 4 years postoperatively. Radiolucent lines were defined as linear radiolucencies adjacent to a sclerotic line, as described by Kobayashi et al. [23, 24]. We used the definition of osteolysis set forth by Schmalzried et al. [23–25].

Statistical analysis

The Tukey-Kramer test was used to evaluate changes in intraoperative blood pressure and SaO₂, from before rasping to during cementing and after stem insertion. Changes in stem subsidence were compared at 6 months, 1 year, 2 years, 3 years, and 4 years postoperatively using analysis of variance (ANOVA) with the Bonferroni correction. A *p* value of <0.05 was considered to be significant. All calculations were made using Statistical Package for the Social Sciences (SPSS), version 16.0 J (SPSS Inc., Chicago, IL).

Results

A total of 38 patients (6 men and 32 women) with 38 involved hips were followed for over 3 months after surgery. The mean age at surgery was 76.2 years (range, 57 to 89 years), and the

mean follow-up period was 21.4 months (range, 3 to 57 months). Sixty-eight percent of patient completed the 3 months of follow-up required for study inclusion.

The preoperative activity level was grade 1 in 9 patients, grade 2 in 21 patients, and grade 3 in 8 patients; no patients were classified as grade 4. The postoperative activity level was grade 1 in 4 patients, grade 2 in 16 patients, and grade 3 in 18 patients; no patients were classified as grade 4. A total of 23 patients (74 %) maintained their preoperative clinical activity level, but 15 patients (26 %) worsened after surgery.

One or more previous histories were noted in in 30 of 38 patients (79 %) as follows: hypertension in 22 patients (58 %), diabetes mellitus in 13 (34 %), respiratory disorder in 6 (16 %), arrhythmia in 5 (13 %), brain infarction in 4 (11 %), and heart failure in 1 (3 %). One or more medications were prescribed preoperatively in 30 of 38 patients (79 %) as follows: hypotensive drugs in 19 patients (50 %), anticoagulant drugs in 12 (32 %), antidiabetic drugs in 10 (26 %), diuretics in 6 (16 %), antihyperlipidemic drugs in 3 (8 %), coronary dilators in 2 (5 %), and antiarrhythmic drug in 1 (3 %). The modus of the anesthesia was anesthesiologist’s preference. General anesthesia with inhalation and intravenous anesthesia in 34 patients (90 %), general anesthesia with inhalation and epidural anesthesia in 2 patients (5 %), and lumbar spinal anesthesia in 2 patients (5 %). Mean fraction of inspiratory oxygen was 0.43 (range; 0.28 to 0.71). Mean intraoperative fluid intake was 1375 ml (range; 600 to 2500 ml), consisting of extracellular fluid (lactate Ringer solution) in 86.5 %, electrolytic solution in 6.5 %, hydroxyethyl starch in 6.4 %, and blood transfusion in 0.6 %. Mean intraoperative urine volume was 318 ml (range; 70 to 900 ml), and blood loss was 175 g (range; 50 to 709 g) within 113 min (range; 80 to 211 min) of mean surgical time. Thus, in-out balance was not dehydrated in all patients. Norepinephrine was administered 9 of 38 patients (24 %) during cementing. As for 33 patients who decreased systolic blood pressure, 8 patients (24 %) received norepinephrine.

Intraoperative SBP decreased significantly during cementing, compared with the value before rasping (109.1 versus 122.2 mmHg; $p=0.0036$; Fig. 1). The intraoperative SBP also decreased significantly after stem insertion, compared with the value before rasping (101.6 versus 122.2 mmHg; $p=0.0001$). Intraoperative SBP increased in 5 patients, decreased between 0 and 20 % in 13 patients, decreased between 20 and 40 % in 19 patients, and decreased more than 40 % in 1 patient. No patients experienced cardiovascular collapse. Intraoperative diastolic blood pressure decreased significantly after stem insertion, compared with the value before rasping (57.9 versus 67.3 mmHg; $p=0.003$). However, all patients maintained steady intraoperative SaO₂ throughout the operation with mean values of 98 % before rasping, 98 % at stem insertion, and 98 % after stem insertion without significant differences. Hypoxia, defined as SaO₂ <94 %, did not occur. Donaldson’s grade was grade 1 in 19 patients (50 %), grade 2 in one patient (3 %), and grade 3 in none (0 %).

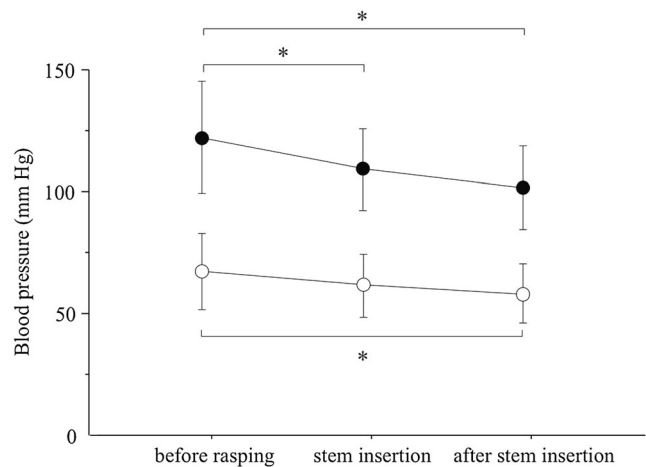


Fig. 1 Intraoperative blood pressure before rasping, during cementing and after stem insertion. Intraoperative systolic and diastolic blood pressure decreased, both during cementing and after stem insertion, compared with their levels before rasping. The black dots represent systolic blood pressure and the white dots represent diastolic blood pressure. * $p<0.05$, Tukey-Kramer test

Perioperative complications occurred in two patients with diabetes mellitus (5 %) who had concurrent infection and dislocation. Both patients were treated with implant removal and Girdlestone procedure. Both patients were excluded at the time of implant removal. No patients experienced perioperative fracture.

On radiographic examination, the cementing grade was A in 31 patients and B in 7 patients. Stem subsidence increased significantly over time: 0.32 mm at 6 months, 0.53 mm at 1 year, 0.91 mm at 2 years, 1.08 mm at 3 years, and 1.13 mm at 4 years (Fig. 2). There were no relationships between stem subsidence and pain because all patients did not have pain after hemiarthroplasty. Stem subsidence at 1 year tended to be greater in a more active patient without significant difference (grade 1 in 0.94 mm, grade 2 in 0.60 mm, and grade 3 in 0.48 mm).

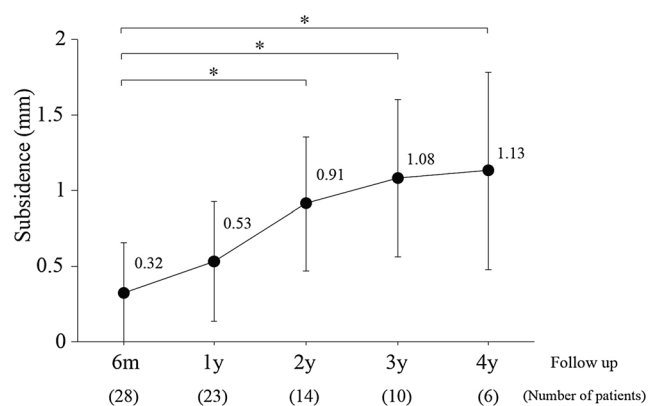


Fig. 2 Change in stem subsidence. Number of patients in 6 months, 1 year, 2 years, 3 years, and 4 years were 28, 23, 14, 10, and 6, respectively. Stem subsidence gradually progressed for 4 years but did not extend beyond 2 mm. * $p<0.005$, analysis of variance with Bonferroni correction

Stem loosening including radiolucent line and osteolysis was not observed.

Discussion

Most of our patients experienced hypotension as a cementing effect during bipolar hemiarthroplasty. Interestingly, 5 patients (13 %) demonstrated hypertension that continued during cementing. Clark et al. [10] reported a fall in stroke volume and cardiac output during the cementation component of hemiarthroplasty for displaced femoral-neck fractures but not during reaming or prosthesis insertion. In a canine-model study, the insertion of cement and prosthesis was followed by severe hypotension, elevated pulmonary artery pressure, decreased systemic vascular resistance, and a 21 % reduction in cardiac output [12]. However, another human study measured arterial blood pressure during total hip arthroplasty and documented slight hypertension in both cemented and uncemented groups at the time of both medullary reaming and insertion of cement and stem, compared with the baseline value [11]. Nolan et al. [13] reported a 20 % increase in mean arterial pressure after insertion of the femoral components in cemented total hip arthroplasty. Our study supports these previous findings.

In the present study, intraoperative SaO₂ remained unchanged before rasping, during cementing and after stem insertion. López-Durán et al. [11] showed similar values for SaO₂; however, their results revealed that partial pressure of oxygen (PaO₂) decreased by 17 mmHg from baseline during cementation. Nolan et al. [13] also reported a decrease in mean PaO₂ of 16 %. While SaO₂ is a noninvasive measurement, it is not precise for measuring hypoxia. This means that we might not have detected slight changes in blood oxygen saturation; however, none of our patients experienced SaO₂ of <94 %, and Donaldson's grade was acceptable in all patients.

Stem subsidence increased significantly over time, and stem loosening was not observed at 4 years of follow-up. Carrington et al. [26] reported that the mean subsidence of the Exeter stem at a mean of 15.7 years postoperatively is 1.82 mm. In another study from the same institution, 89 % of patients demonstrated stem subsidence less than 2 mm at a mean of 8.9 years of follow-up [22]. In the present study, all subsidence was within 2 mm. Thus, we believe that our cementing technique is valid. Generally, the thickness of the cement mantle depends on the surgeon's preference of technique, such as the complete cement mantle technique [27–29] or the line-to-line technique (also known as canal filling or tight-fit technique) [14, 30–32]. We prefer the latter because of its potential advantages: ease of removing mechanically weak cancellous bone, ease of obtaining a neutral stem position [15, 32], ease of obtaining initial stability of the stem [14, 31, 33], and the ability to apply a higher intramedullary cement pressure during stem insertion.

In bipolar hemiarthroplasty for displaced femoral-neck fractures in elderly patients, the evidence suggests that both traditional and modern cemented prostheses provide more favorable clinical outcomes than do uncemented implants [4, 5, 7]. Cemented hemiarthroplasty has a significantly lower rate of intraoperative and postoperative implant-related complications [6]. This is an advantage since a loose prosthesis can cause pain, delay patient mobility, and require further surgery [34]. Moreover, the UK national analysis of matched patients indicates that midterm revision and perioperative chest infection rates are significantly lower with cemented prostheses. This suggests that cemented hemiarthroplasty is the current gold standard for the treatment of displaced femoral-neck fractures in elderly patients [35]. In the present study, 74 % of patients maintained their preoperative clinical activity level.

There are several limitations to this study. First, we did not evaluate blood pressure before surgery, comparing only indirect values taken during the three phases of cementing in order to document the cementing effect. Real-time monitoring of direct blood pressure with arterial line would be more reliable. Second, we did not evaluate PaO₂. Ideally, hypoxia should be monitored using PaO₂, but this is an invasive procedure so we deferred to the anesthesiologist's preference of SaO₂ as well as blood pressure and did not observe any catastrophic events. Third, it is true that our patient population was inhomogeneous due to retrospective nature. Intraoperative blood pressure and perioperative complication could be influenced by past history of hypertension, arteriosclerosis obliterans, the other medication, or physical status by the American Society of Anaesthesiologists's classification. Fourth, we did not validate the measurement of stem subsidence. The measurement may have included some error, although it was a simple and widely accepted method. Fifth, this is a case series of patients who received cemented implants. It is true that stem subsidence were actually small but getting increase. This implies characteristics of cemented stem. But, only 6 patients completed 4 years follow-up. Further study is needed to directly compare cemented and uncemented hemiarthroplasty.

In conclusion, cemented bipolar hemiarthroplasty for displaced femoral-neck fractures in elderly patients leads to hypotension but no significant hypoxia. Stem subsidence is acceptable, and the clinical outcomes are favorable.

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Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Conflict of interest The authors declare that they have no competing interests.

References

- Hagino H, Sakamoto K, Harada A, Nakamura T, Mutoh Y, Mori S, Endo N, Nakano T, Itoi E, Kita K, Yamamoto N, Aoyagi K, Yamazaki K, Committee on Osteoporosis of The Japanese Orthopaedic Association (2010) Nationwide one-decade survey of hip fractures in Japan. *J Orthop Sci* 15:737–745
- Bhandari M, Devereaux PJ, Tornetta P 3rd, Swiontkowski MF, Berry DJ, Haidukewych G, Schemitsch EH, Hanson BP, Koval K, Dirschl D, Leece P, Keel M, Petrisor B, Heetveld M, Guyatt GH (2005) Operative management of displaced femoral neck fractures in elderly patients. An international survey. *J Bone Joint Surg Am* 87:2122–2130
- Frihagen F, Nordsetten L, Madsen JE (2007) Hemiarthroplasty or internal fixation for intracapsular displaced femoral neck fractures: randomised controlled trial. *BMJ* 335:1251–1254
- Parker MJ, Gurusamy KS, Azegami S (2010) Arthroplasties (with and without bone cement) for proximal femoral fractures in adults. *Cochrane Database Syst Rev* 6, CD001706. doi:10.1002/14651858.CD001706.pub4
- Parker MI, Pryor G, Gurusamy K (2010) Cemented versus uncemented hemiarthroplasty for intracapsular hip fractures: a randomised controlled trial in 400 patients. *J Bone Joint Surg (Br)* 92:116–122
- Taylor F, Wright M, Zhu M (2012) Hemiarthroplasty of the hip with and without cement: a randomized clinical trial. *J Bone Joint Surg Am* 94:577–583
- Khan RJ, MacDowell A, Crossman P, Datta A, Jallali N, Arch BN, Keene GS (2002) Cemented or uncemented hemiarthroplasty for displaced intracapsular femoral neck fractures. *Int Orthop* 26:229–232
- Murphy P, Edelist G, Byrick RJ, Kay JC, Mullen JB (1997) Relationship of fat embolism to haemodynamic and echocardiographic changes during cemented arthroplasty. *Can J Anaesth* 44:1293–1300
- Hagio K, Sugano N, Takashina M, Nishii T, Yoshikawa H, Ochi T (2003) Embolic events during total hip arthroplasty: an echocardiographic study. *J Arthroplasty* 18:186–192
- Clark DI, Ahmed AB, Baxendale BR, Moran CG (2001) Cardiac output during hemiarthroplasty of the hip. A prospective, controlled trial of cemented and uncemented prostheses. *J Bone Joint Surg (Br)* 83:414–418
- López-Durán L, García-López A, Durán L, Hurtado J, Ruiz C, Rodrigo JL (1997) Cardiopulmonary and haemodynamic changes during total hip arthroplasty. *Int Orthop* 21:253–258
- Wheelwright EF, Byrick RJ, Wigglesworth DF, Kay JC, Wong PY, Mullen JB, Waddell JP (1993) Hypotension during cemented arthroplasty. Relationship to cardiac output and fat embolism. *J Bone Joint Surg (Br)* 75:715–723
- Nolan JP (1994) Arterial oxygenation and mean arterial blood pressure in patients undergoing total hip replacement: cemented versus uncemented components. *Anaesthesia* 49:293–299
- Skinner JA, Todo S, Taylor M, Wang JS, Pinskerova V, Scott G (2003) Should the cement mantle around the femoral component be thick or thin? *J Bone Joint Surg (Br)* 85:45–51
- Scheerlinck T, Casteleyn PP (2006) The design features of cemented femoral hip implants. *J Bone Joint Surg (Br)* 88:1409–1418
- Ito H, Hirayama T, Tanino H, Matsuno T, Minami A (2007) Tight fit technique in primary hybrid total hip arthroplasty for patients with hip dysplasia. *J Arthroplasty* 22:57–64
- Iida S, Fujitsuka M, Tanno T, Shinada Y, Kin T, Ikenoue S (2003) Results and complications of hemiarthroplasty for intracapsular fracture of the femoral neck. *J Eastern Jpn Assoc Orthop Traumatol [Jpn]* 15:621–624
- Donaldson AJ, Thomson HE, Harper NJ, Kenny NW (2009) Bone cement implantation syndrome. *Br J Anaesth* 102:12–22
- Mulroy WF, Estok DM, Harris WH (1995) Total hip arthroplasty with use of so-called second-generation cementing techniques. A fifteen-year-average follow-up study. *J Bone Joint Surg Am* 77:1845–1852
- Gruen TA, McNeice GM, Amstutz HC (1979) “Modes of failure” of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 141:17–27
- Fowler JL, Gie GA, Lee AJ, Ling RS (1988) Experience with the Exeter total hip replacement since 1970. *Orthop Clin North Am* 19:477–489
- Williams HD, Browne G, Gie GA, Ling RS, Timperley AJ, Wendover NA (2002) The Exeter universal cemented femoral component at 8 to 12 years. A study of the first 325 hips. *J Bone Joint Surg (Br)* 84:324–334
- Kobayashi S, Takaoka K, Saito N, Hisa K (1997) Factors affecting aseptic failure of fixation after primary Charnley total hip arthroplasty. Multivariate survival analysis. *J Bone Joint Surg Am* 79:1618–1627
- Schmalzried TP, Jasty M, Harris WH (1992) Periprosthetic bone loss in total hip arthroplasty. Polyethylene wear debris and the concept of the effective joint space. *J Bone Joint Surg Am* 74:849–863
- Konttinen YT, Zhao D, Beklen A, Ma G, Takagi M, Kivelä-Rajamäki M, Ashammakhi N, Santavirta S (2005) The microenvironment around total hip replacement prostheses. *Clin Orthop Relat Res* 430:28–38
- Carrington NC, Sierra RJ, Gie GA, Hubble MJ, Timperley AJ, Howell JR (2009) The Exeter Universal cemented femoral component at 15 to 17 years: an update on the first 325 hips. *J Bone Joint Surg (Br)* 91:730–737
- Ebrahimzadeh E, Sarmiento A, McKellop HA, Llinas A, Gogan W (1994) The cement mantle in total hip arthroplasty. Analysis of long-term radiographic results. *J Bone Joint Surg Am* 76:77–87
- Kawate K, Maloney WJ, Bragdon CR, Biggs SA, Jasty M, Harris WH (1998) Importance of a thin cement mantle. Autopsy studies of eight hips. *Clin Orthop Relat Res* 355:70–76
- Ramaniraka NA, Rakotomanana LR, Leyvraz PF (2000) The fixation of the cemented femoral component. Effects of stem stiffness, cement thickness and roughness of the cement-bone surface. *J Bone Joint Surg (Br)* 82:297–303
- Langlais F, Kerboul M, Sedel L, Ling RS (2003) The ‘French paradox’. *J Bone Joint Surg (Br)* 85:17–20
- Kerboul L, Hamadouche M, Courpied JP, Kerboul M (2004) Long-term results of Charnley-Kerboul hip arthroplasty in patients younger than 50 years. *Clin Orthop Relat Res* 418:112–118
- Scheerlinck T, de Mey J, Deklerck R, Noble PC (2006) CT analysis of defects of the cement mantle and alignment of the stem: in vitro comparison of Charnley-Kerboul femoral hip implants inserted line-to-line and undersized in paired femora. *J Bone Joint Surg (Br)* 88:19–25
- Hamadouche M, Boutin P, Daussange J, Bolander ME, Sedel L (2002) Alumina-on-alumina total hip arthroplasty: a minimum 18.5-year follow-up study. *J Bone Joint Surg Am* 84-A:69–77
- Ahn J, Man LX, Park S, Sodl JF, Esterhai JL (2008) Systematic review of cemented and uncemented hemiarthroplasty outcomes for femoral neck fractures. *Clin Orthop Relat Res* 466:2513–2518
- Jameson SS, Jensen CD, Elson DW, Johnson A, Nachtsheim C, Rangan A, Muller SD, Reed MR (2013) Cemented versus cementless hemiarthroplasty for intracapsular neck of femur fracture—a comparison of 60,848 matched patients using national data. *Injury* 44:730–734