Clin Orthop Relat Res (2015) 473:3197–3203
DOI 10.1007/s11999-015-4402-y

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

Are There Long-term Benefits to Cementing the Metaphyseal Stem in Hip Resurfacing?

Harlan C. Amstutz MD, Michel J. Le Duff MA, Sandeep K. Bhaurla MPH

Received: 23 January 2015 / Accepted: 4 June 2015 / Published online: 23 June 2015

Abstract

Background Cementing the metaphyseal stem during hip resurfacing surgery improves the initial fixation of the femoral component. However, there may be long-term detrimental effects such as stress shielding or an increased risk of thermal necrosis associated with this technique.

Questions/purposes We compared (1) long-term survivorship free from radiographic femoral failure, (2) validated pain scores, and (3) radiographic evidence of component fixation between hips resurfaced with a cemented metaphyseal stem and hips resurfaced with the metaphyseal stem left uncemented.

Methods We retrospectively selected all the patients who had undergone bilateral hip resurfacing with an uncemented metaphyseal stem on one side, a cemented metaphyseal stem on the other side, and had both surgeries performed between July 1998 and February 2005. Forty-three patients matched these inclusion criteria. During that period, the indications for cementing the stem evolved in the practice of the senior author (HCA), passing through four phases; initially, only hips with large femoral defects had a cemented stem, then all stems were cemented, then all stems were left uncemented. Finally, stems were cemented for patients receiving small femoral components (< 48 mm) or having large femoral defects (or both). Of the 43 cemented stems, two, 13, 0, and 28 came from each of those four periods. All 43 patients had complete followup at a minimum of 9 years (mean, 143 ± 21 months for the uncemented stems; and 135 ± 22 months for the cemented stems; p = 0.088). Survivorship analyses were performed with Kaplan-Meier and Cox proportional hazards ratios using radiographic failure of the femoral component as the endpoint. Pain was assessed with University of California Los Angeles (UCLA) pain scores, and radiographic femoral failure was defined as complete radiolucency around the metaphyseal stem or gross migration of the femoral component.

Results There were four failures of the femoral component in the press-fit stem group while the cemented stem group had no femoral failures (p = 0.0471). With the numbers available, we found no differences between the two groups regarding pain relief or radiographic appearance other than in patients whose components developed loosening.

Conclusions Cementing the metaphyseal stem improves long-term implant survival and does not alter long-term pain relief or the radiographic appearance of the proximal femur as had been a concern based on the results of finite element studies. We believe that patients with small component sizes and large femoral head defects have more to gain from the use of this technique which adds surface area for fixation, and there is no clinical downside to cementing the stem in patients with large component sizes.

One of the authors certifies that he (HCA) or she, or a member of his or her immediate family, has or may receive payments or benefits, during the study period, an amount of USD 10,000-USD 100,000 from MicroPort Orthopedics Inc (Arlington, TN, USA).
All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research®* editors and board members are on file with the publication and can be viewed on request.
Clinical Orthopaedics and Related Research® neither advocates nor endorses the use of any treatment, drug, or device. Readers are encouraged to always seek additional information, including FDA approval status, of any drug or device before clinical use.
Each author certifies that his or her institution approved or waived approval for the reporting of this investigation and that all investigations were conducted in conformity with ethical principles of research.

H. C. Amstutz (✉), M. J. Le Duff, S. K. Bhaurla
Joint Replacement Institute, St. Vincent Medical Center, 2200 West Third Street, Suite 400, Los Angeles, CA 90057, USA
e-mail: harlanamstutz@dochs.org

Level of Evidence Level III, therapeutic study

Introduction

Metal-on-metal hip resurfacing has been considered an effective way to treat young and active patients with end-stage osteoarthritis since the 1990s [9, 13, 14, 30, 31]. However, aseptic failure of the femoral component (component loosening or femoral neck fracture) has been reported as one of the main modes of failure, particularly in the early reports [3, 12, 19, 21, 23, 25]. The association between smaller sizes of the femoral component and higher failure rate of hip resurfacing [22, 26] suggests that increasing the fixation area between the bone and the component could provide more initial and enduring component stability. All currently available hip resurfacing prostheses feature a metaphyseal stem, typically left uncemented, which helps to facilitate proper alignment for insertion of the femoral component. Cementing this metaphyseal stem increases the area for fixation between the bone and the prosthesis, but this increases the total amount of bone cement needed for fixation, and several studies suggest that the heat generated from the cementing process could lead to thermal necrosis of the surrounding cancellous bone [15, 18, 20], which could in turn cause femoral neck fracture or femoral loosening. Additionally, cementing the stem may alter the load transfer between the femoral component and the femoral neck, leading to adverse modifications of the proximal femur [24, 29].

A previous study showed the short-term value of this technique [6], but to this date, there have been no long-term clinical studies assessing the safety and effectiveness of stem cementation or its potential adverse effects such as femoral neck narrowing or femoral neck fracture.

We therefore sought to determine whether (1) survivorship free from radiographic loosening of the femoral component would decrease, (2) hip scores would vary, or (3) frequency of radiolucencies or narrowing of the femoral neck would differ between femoral components implanted with cemented and uncemented metaphyseal stems.

Materials and Methods

From the senior author's (HCA) database, we retrospectively selected all the patients who had undergone bilateral hip resurfacing with an uncemented metaphyseal stem on one side, a cemented metaphyseal stem on the other side, and had both surgeries performed between July 1998 and February 2005. Forty-three patients matched these inclusion criteria and none was lost to followup. Fourteen patients underwent one-stage bilateral procedures (and in these cases the hip with the largest defects received the cemented stem), while the remaining 29 had both hips resurfaced in two stages with a mean time between procedures of 23.9 ± 17.8 months. During that period, the indications for cementing the stem evolved in the senior author's practice, passing through four phases to determine efficacy and safety of the technique. Initially, only a few hips with large femoral defects had a cemented stem, then, all stems were cemented, and then all stems were left uncemented, and finally (our current indication), stems were cemented for patients with small femoral components (< 48 mm) or large defects (or both). The last phase was initiated after preliminary data indicated that those hips were most at risk for loosening. Of the 43 cemented stems, two, 13, 0, and 28 came from each of those four periods. Concurrently, the surgical technique used for preparation of the femoral head also evolved in three generations described in a previous report [5] (Table 1). This variable was taken into consideration in our subsequent analysis. All 43 patients had complete followup at a minimum of 9 years (mean, 143 ± 21 months for patients with uncemented stems and 135 ± 22 months for patients with cemented stems; p = 0.088).

The patient's demographic characteristics were typical of those for patients having hip resurfacing. Their mean age at surgery was 51.1 ± 9.6 years. There were 11 female patients (26%) and 32 male patients (74%). The diagnoses were primary osteoarthritis in 33 patients (77%), developmental dysplasia of the hip in six (14%), osteonecrosis in three (7%), and inflammatory osteoarthritis in one (2%). The mean weight of the patients was 79.0 ± 16.4 kg and

Table 1. Evolution of the femoral fixation technique throughout the series

Femoral fixation technique	Fixation area	Cystic material removal	Drying
1st generation (10 hips with uncemented stems and 1 hip with a cemented stem)	No drill holes or in dome area only	Use of curette only	No suction for the first 100 hips then dome suction only
2nd generation (25 hips with uncemented stems and 32 hips with cemented stems)	Increased number of drill holes in dome and some in chamfered area	Use of curette + high speed burr	Dome suction only
3rd generation current technique (8 hips with uncemented stems and 10 hips with cemented stems)	Additional drill holes in chamfer	Use of curette + high speed burr	Use of dome and lesser trochanteric suction Use of Co_2 blow dry device

Table 2. Comparative reconstruction characteristics for hips with press-fit stems versus hips with cemented stems

Variable	Uncemented stems Mean ± SD	Cemented stems Mean ± SD	p value
Femoral head size	46.7 ± 4.1	47.0 ± 4.1	0.6746
Cup abduction	45.0 ± 6.8	45.3 ± 5.7	0.7823
Cup anteversion	16.2 ± 5.9	16.5 ± 8.6	0.8581
Metaphyseal stem to femoral shaft angle	136.3 ± 7.2	138.7 ± 7.2	0.1233
	Frequency	Frequency	
Femoral head defects			0.3655
< 1 cm	30	26	
≥ 1 cm	13	17	

mean height was 174.3 ± 9.4 cm. Both groups were comparable regarding femoral defects, component sizes, and component orientation (Table 2). All surgeries were performed using the Conserve®Plus Hip Resurfacing System (MicroPort Orthopedics Inc, Arlington, TN, USA), a metal-on-metal hybrid resurfacing device that uses cobalt-chromium-molybdenum bearings and a smooth metaphyseal stem designed to facilitate alignment of the component. No modification of the stem portion of the component (which has a slight taper) was made, whether the stem was cemented or uncemented. The stem hole was drilled 2 mm beyond the actual stem length when it was cemented and 2 mm short of the full length when left uncemented to insure intimate contact [4]. The Conserve®Plus device is approved by the FDA. The overall surgical technique for implantation of the Conserve®Plus device has been described [2, 4]. A wide posterior surgical exposure and capsulectomy were performed, which in our view facilitate careful preparation of the femoral head to avoid fracture. All hips had moderate to severe osteoarthritis and were judged to be sufficiently vascular to maintain bone quality as there is a degree of hyperemia associated with osteoarthritis.

When cementing the stem, a thin coating of doughy acrylic (Simplex P™, Stryker® Corporation, Kalamazoo, MI, USA) is first applied on its entire length. Then, the dome suction device is removed and acrylic is finger pressurized into the dome hole for 30 to 45 seconds and also pressurized into femoral defects and the cylindrically reamed portion of the head. The femoral component then is inserted and seated with light mallet taps.

Patients were seen postoperatively at 6 weeks, 4 months, 1 year, and yearly thereafter, at which time clinical data were collected. AP radiographs were obtained with the patients supine, and the University of California Los Angeles (UCLA) hip scoring system [9] was used to evaluate patients' progress. Researchers used UCLA pain scores to assess clinical outcomes of cementing the stem versus not cementing. All three authors reviewed the patients' most recent AP radiographs to identify hips with radiolucencies around the metaphyseal stem. We also compared the patients' most recent radiographs with their first postoperative films to identify any narrowing of 10% or greater of the mediolateral femoral neck [16, 17, 27]. Component positioning (femoral stem-to-shaft angle, cup abduction angle, and cup anteversion angle) were measured as previously described [8]. A Johnson lateral radiograph (obtained with the patient supine) also was reviewed but the quality of the technique often varied so that AP measurement of the neck thickness was not reliable.

Researchers compared UCLA pain scores between groups using two-tailed paired Student's t-tests. The time to radiographic femoral failure was used as an endpoint to calculate Kaplan-Meier survival estimates for both groups. Radiographic femoral failure was defined as complete radiolucency around the metaphyseal stem or gross migration of the femoral component. The log-rank test was used to compare the survival curves. The Cox proportional hazard ratio was used to determine the influence of the femoral preparation technique on femoral survivorship. Alpha was set at 0.05. All data were analyzed using Intercooled Stata® 6.0 (Stata® Corp, College Station, TX, USA).

Results

The hips with cemented stems showed better femoral survivorship (free of radiographic femoral failure) compared with the hips with uncemented stems (Fig. 1) (p = 0.0471). The Kaplan-Meier survivorship at 5 years was 95.4% (95% CI, 82.7%–98.8%) for the hips with uncemented stems, and 100% for the hips with cemented stems. At 10 years, the survivorship was 90.5% (95% CI, 76.6%–96.3%) for the hips with uncemented stems, and 100% for the hips with cemented stems. Because there were no failures in the

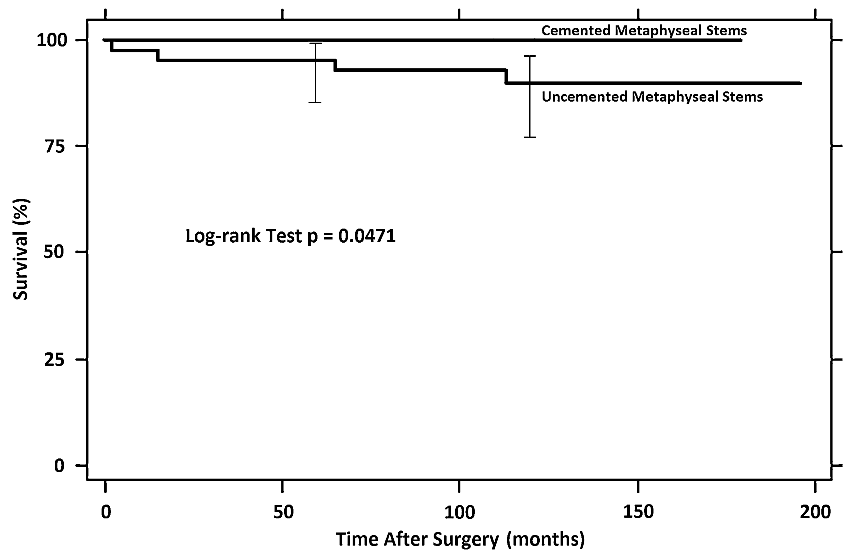

Fig. 1 A comparative survivorship analysis of hips resurfaced with uncemented stems versus hips with cemented stems is shown. The time to radiographic femoral failure was used as an endpoint.

cemented group, we were unable to provide a hazard ratio for failure when we compared these hips with those in the uncemented group. There was no association between femoral head preparation technique and femoral failure rate in this group of 86 hips (p = 0.915). One patient had pain on the side of the hip with a cementless stem, which showed a complete radiolucency around the metaphyseal stem. This patient was pending revision surgery at the time of writing and therefore the patient's results were counted as a failure in our analysis (Fig. 2). In addition to this hip, three others with uncemented stems had failed (Table 3) and all had revision surgery to total hip replacements (two secondary to loosening of the femoral component at 65 and 112 months, and one secondary to a fracture of the femoral neck at 2 months). In the cemented stem group, two hips were revised, one had a deep infection develop at 13 months and the other had a loose acetabular component at 108 months. There were no aseptic femoral failures in that group.

We found no differences in preoperative and last followup UCLA pain scores between the two groups. The mean UCLA preoperative pain scores were 3.7 ± 1.3 for the group with uncemented stems and 3.7 ± 1.3 for the group with cemented stems (p = 0.7816). The mean UCLA postoperative pain scores were 9.6 ± 0.8 for the group with uncemented stems and 9.4 ± 0.9 for the group with cemented stems (p = 0.5683).

There were no other differences in radiographic findings between the groups. Three hips with uncemented stems and one with a cemented stem showed evidence of femoral neck narrowing greater than 10% on the last postoperative radiograph (p = 0.3173). All four hips were asymptomatic.

Discussion

Cementing the stem during hip resurfacing surgery expands the area of fixation and helps to improve the initial fixation of the femoral component. However, there is a concern that this technique might have long-term detrimental effects related to stress shielding [24, 29] or thermal necrosis associated with the increase in overall cement needed for component fixation [15, 18, 20]. Our study compared survivorship, hip scores, and other radiographic findings between hips resurfaced with a cemented metaphyseal stem and hips resurfaced with a press-fit metaphyseal stem.

Our study has several limitations. First, there is a risk of selection bias with at least three filters: candidates for hip resurfacing, candidates for bilateral resurfacing within a certain time, and candidates for use versus nonuse of cement. However, we believe that the selection of patients undergoing bilateral procedures adds strength to the study of the research question by eliminating all patient-related extraneous variables. Second, the data presented in this study were collected after implantation of the Conserve® Plus Hip Resurfacing System with regular Simplex P bone cement applied in its doughy stage and the thickness of the cement mantle is 1 mm. Our results cannot be inferred to other hip resurfacing devices such as the Birmingham Hip Resurfacing System for which the cement is applied in its liquid state to accommodate a tight fit (with a negligible cement mantle). Third, the surgical technique used to implant the femoral component has evolved with time in our series, improving the survivorship results as previously reported [7], and more hips were implanted with the early technique in the group with uncemented stems than in the

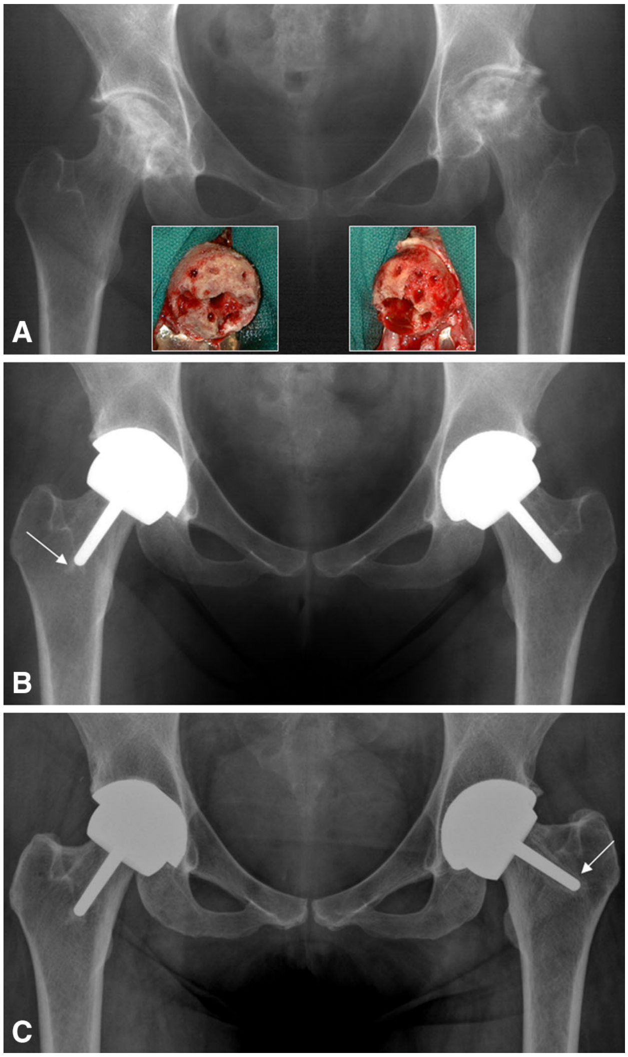

Fig. 2A–C The AP radiographs of the hips of a 31-year-old female with bilateral osteonecrosis secondary to systemic lupus erythematosus are shown. Surgery was performed on both hips in one stage. (**A**) A preoperative radiograph has insets of intraoperative photographs of the femoral heads after bone preparation. The patient's surgery was performed before increased irrigation and suction techniques were implemented. The bone quality was visibly poor in both heads with slightly larger defects on the right. (**B**) No evidence of femoral radiolucency was seen on the immediate postoperative radiograph, with the stem cemented on the right (arrow). (**C**) Four years after surgery, a large radiolucency around the uncemented stem on the left can be seen, with a sclerotic halo of bone surrounding the stem tip. The component also has tipped into a more varus distal position. Fourteen years after surgery, the patient has begun to experience pain associated with weightbearing activities and is pending revision surgery. Her current UCLA scores for pain are six for the left hip, 10 for the right hip, and her walking, function, and activity scores are 8, 8, and 4, respectively. (Reprinted from Amstutz HC, Le Duff MJ, Campbell PA, Dorey FJ. The effects of technique changes on aseptic loosening of the femoral component in hip resurfacing: results of 600 Conserve® Plus with a 3–9 year follow-up. *J Arthroplasty*. 2007;22:481–489.)

group with cemented stems. However, we found no association between femoral head preparation technique and femoral failure rate in this particular cohort of patients, suggesting that the difference in survivorship between the two groups was associated with cementation of the stems. In addition, the changes in indications for cementation of the metaphyseal stem could have introduced a selection bias but the comparison of the reconstruction characteristics (Table 1) shows otherwise. Fourth, only AP radiographs were used to determine narrowing of the femoral neck after surgery. Because a large number of patients live out of state and had their radiographs taken outside our center, the consistency of the Johnson lateral views provided did not allow us to make precise comparative measurements of this variable with time and therefore we limited our analysis to the frontal plane. In addition, other means of investigation of bone quality (such as bone mineral density scans) would have been of value to further determine if any stress shielding was occurring in the femoral neck but unfortunately these data were not available. We also do not have data addressing soft tissue structures about the hip, but the use or avoidance of cement is unlikely to influence the development of metallosis or adverse local tissue reactions.

Short-term efficacy of cementing the metaphyseal stem to reduce the risk of aseptic failure of the femoral component has been reported [6, 11], but the effect of stem cementation on the long-term integrity of the femoral head and neck cannot be predicted without a clinical study with sufficient followup. Although this technique has been used in other centers, to our knowledge, no reports have been published for comparison with our results. A strength of our study was that the possible effects of variations in patient activity during such a long time were controlled by the study design. Our current data suggest that cementing the stem does improve long-term implant survival and does not alter long-term pain relief or the radiographic appearance of the proximal femur.

We found no differences between cemented and cementless stems in terms of UCLA hip pain scores. This result correlates with our previous findings in a study with shorter followup and a different cohort of patients [6]. In addition, the postoperative UCLA pain scores recorded in this study were high and comparable to those of the previous publication. This is consistent with the stability of pain scores with time after hip resurfacing [13, 28, 30]. This is in contrast with studies of pain scores after cemented vs cementless fixations in conventional THAs where the presence of cement can contribute to better pain relief [1].

We found no radiographic evidence suggestive of adverse events related to stem cementation. There were no neck fractures among the hips with a cemented stem, no failures secondary to osteonecrosis, and no radiographic evidence that cementing the stem increases the chances of adverse neck remodeling as had been a concern in prior studies [24,

Table 3. Summary of patients with aseptic femoral failure (n = 4)

Reason for revision	Femoral loosening	Femoral loosening	Femoral loosening	Early femoral neck fracture
Months to revision	65	Revision pending	113	2
Cup abduction (degrees)	43	42	53	47
Cup anteversion (degrees)	11	17	26	8
Stem to femoral shaft angle (degrees)	141	130	138	136
UCLA activity score	9	4	7	Not available
Femoral defect size	> 1 cm	> 1 cm	None	None
Preoperative diagnosis	OA	ON	OA	OA
Sex	Male	Female	Male	Male
Component size (mm)	46	36	46	50

UCLA = University of California Los Angeles; OA = osteoarthritis; ON = osteonecrosis.

29]. However, our sample size was small, and the indications for cementing the stems did evolve with time, therefore, to some degree, this remains an open question.

We believe that cementing the stem is more important for patients with small component sizes and large femoral head defects as these patients historically have been at greater risk of experiencing failure after hip resurfacing [10]. However, it does not appear to be detrimental to cement the stem in patients with large component sizes. Cementing the metaphyseal stem is an effective method to improve initial fixation of the femoral component and to prevent its loosening at long-term.

References

1. Abdulkarim A, Ellanti P, Motterlini N, Fahey T, O'Byrne JM. Cemented versus uncemented fixation in total hip replacement: a systematic review and meta-analysis of randomized controlled trials. *Orthop Rev (Pavia).* 2013;15:e8.
2. Amstutz HC. "Top 10" technical pearls for successfully performing hip resurfacing arthroplasty. *Techniques Orthop.* 2010;25:73–79.
3. Amstutz HC, Beaulé PE, Dorey FJ, Le Duff MJ, Campbell PA, Gruen TA, Metal-on-metal hybrid surface arthroplasty: two to six year follow-up. *J Bone Joint Surg Am*, 2004;86:28–39.
4. Amstutz HC, Beaulé PE, Dorey FJ, Le Duff MJ, Campbell PA, Gruen TA. Metal-on-metal hybrid surface arthroplasty: surgical technique. *J Bone Joint Surg Am.* 2006;88(suppl 1 part 2):234–249.
5. Amstutz HC, Le Duff MJ. Eleven years of experience with metal-on-metal hybrid hip resurfacing: a review of 1000 conserve plus. *J Arthroplasty.* 2008;23(6 suppl 1)36–43.
6. Amstutz HC, Le Duff MJ. Cementing the metaphyseal stem in metal-on-metal resurfacing: when and why. *Clin Orthop Relat Res*, 2009;467:79–83.
7. Amstutz HC, Le Duff MJ, Campbell PA, Dorey FJ. The effects of technique changes on aseptic loosening of the femoral component in hip resurfacing: results of 600 Conserve Plus with a 3–9 year follow-up. *J Arthroplasty*. 2007;22:481–489.
8. Amstutz HC, Le Duff MJ, Johnson AJ. Socket position determines hip resurfacing 10-year survivorship. *Clin Orthop Relat Res.* 2012;470:3127–3133.
9. Amstutz HC, Thomas BJ, Jinnah R, Kim W, Grogan T, Yale C. Treatment of primary osteoarthritis of the hip: a comparison of total joint and surface replacement arthroplasty. *J Bone Joint Surg Am.* 1984;66:228–241.
10. Australian Orthopaedic Association National Joint Replacement Registry. Annual Report 2014. Available at: https://aoanjrr.dmac.adelaide.edu.au/en/annual-reports-2014. Accessed May 15, 2015.
11. Campbell P, Takamura K, Lundergan W, Esposito C, Amstutz HC. Cement technique changes improved hip resurfacing longevity: implant retrieval findings. *Bull NYU Hosp Jt Dis.* 2009;67:146–153.
12. Carrothers AD, Gilbert RE, Jaiswal A, Richardson JB. Birmingham hip resurfacing: the prevalence of failure. *J Bone Joint Surg Br.* 2010;92:1344–1350.
13. Coulter G, Young DA, Dalziel RE, Shimmin AJ. Birmingham hip resurfacing at a mean of ten years: results from an independent centre. *J Bone Joint Surg Br.* 2012;94:315–321.
14. Daniel J, Pradhan C, Ziaee H, Pynsent PB, McMinn DJ. Results of Birmingham hip resurfacing at 12 to 15 years: a single-surgeon series. *Bone Joint J.* 2014;96:1298–1306.
15. Gill HS, Campbell PA, Murray DW, De Smet KA. Reduction of the potential for thermal damage during hip resurfacing. *J Bone Joint Surg Br.* 2007;89:16–20.
16. Hing CB, Young DA, Dalziel RE, Bailey M, Back DL, Shimmin AJ. Narrowing of the neck in resurfacing arthroplasty of the hip: a radiological study. *J Bone Joint Surg Br.* 2007;89: 1019–1024.
17. Ho KK, Beazley J, Parsons N, Costa ML, Foguet P. Narrowing of the femoral neck after resurfacing arthroplasty of the hip: a comparison of cemented and uncemented femoral components. *Hip Int.* 2010;20:542–546.
18. Janssen D, Srinivasan P, Scheerlinck T, Verdonschot N. Effect of cementing technique and cement type on thermal necrosis in hip resurfacing arthroplasty: a numerical study. *J Orthop Res.* 2012;30:364–370.
19. Lazarinis S, Milbrink J, Hailer NP. Avascular necrosis and subsequent femoral neck fracture 3.5 years after hip resurfacing: a highly unusual late complication in the absence of risk factors. A case report. *Acta Orthop.* 2008;79:763–768.
20. Little JP, Gray HA, Murray DW, Beard DJ, Gill HS. Thermal effects of cement mantle thickness for hip resurfacing. *J Arthroplasty.* 2008;23:454–458.
21. Marker DR, Seyler TM, Jinnah RH, Delanois RE, Ulrich SD, Mont MA. Femoral neck fractures after metal-on-metal total hip resurfacing: a prospective cohort study. *J Arthroplasty.* 2007;22(7 suppl 3):66–71.
22. McBryde CW, Theivendran K, Thomas AM, Treacy RB, Pynsent PB. The influence of head size and sex on the outcome of Birmingham hip resurfacing. *J Bone Joint Surg Am.* 2010;92:105–112.

23. Mont MA, Seyler TM, Ulrich SD, Beaule PE, Boyd HS, Grecula M,J Goldberg VM, Kennedy WR, Marker DR, Schmalzried TP, Sparling EA, Vail TP, Amstutz HC. Effect of changing indications and techniques on total hip resurfacing. *Clin Orthop Relat Res.* 2007;465:63–70.
24. Pal B, Gupta S, New AM. A numerical study of failure mechanisms in the cemented resurfaced femur: effects of interface characteristics and bone remodelling. *Proc Inst Mech Eng H.* 2009;223:471–484.
25. Shimmin AJ, Back D. Femoral neck fractures following Birmingham hip resurfacing: a national review of 50 cases. *J Bone Joint Surg Br.* 2005;87:463–464.
26. Shimmin AJ, Walter WL, Esposito C. The influence of the size of the component on the outcome of resurfacing arthroplasty of the hip: a review of the literature. *J Bone Joint Surg Br.* 2010;92:469–476.
27. Takamura KM, Yoon J, Ebramzadeh E, Campbell PA, Amstutz HC. Incidence and significance of femoral neck narrowing in the first 500 Conserve® Plus series of hip resurfacing cases: a clinical and histologic study. *Orthop Clin North Am.* 2011;42:181–193, viii.
28. Tan TL, Le Duff MJ, Takamura KM, Amstutz HC. Do clinical and quality of life scores change over time after hip resurfacing? *Hip Int.* 2015;25:146–151.
29. Taylor M. Finite element analysis of the resurfaced femoral head. *Proc Inst Mech Eng H.* 2006;220:289–297.
30. Treacy RB, McBryde CW, Shears E, Pynsent PB. Birmingham hip resurfacing: a minimum follow-up of ten years. *J Bone Joint Surg Br.* 2011;93:27–33.
31. Zylberberg AD, Nishiwaki T, Kim PR, Beaulé PE. Clinical results of the Conserve Plus metal on metal hip resurfacing: an independent series. *J Arthroplasty.* 2015;30:68–73.