International Orthopaedics (SICOT) (2013) 37:9–14
DOI 10.1007/s00264-012-1738-8

REVIEW ARTICLE

Is there evidence for accelerated polyethylene wear in uncemented compared to cemented acetabular components? A systematic review of the literature

Hugo C. van der Veen · Hans-Peter W. van Jonbergen · Rudolf W. Poolman · Sjoerd K. Bulstra · Jos J. A. M. van Raay

Received: 23 September 2012 / Accepted: 21 November 2012 / Published online: 11 December 2012

Abstract Joint arthroplasty registries show an increased rate of aseptic loosening in uncemented acetabular components as compared to cemented acetabular components. Since loosening is associated with particulate wear debris, we postulated that uncemented acetabular components demonstrate a higher polyethylene wear rate than cemented acetabular components in total hip arthroplasty. We performed a systematic review of the peer-reviewed literature, comparing the wear rate in uncemented and cemented acetabular components in total hip arthroplasty. Studies were identified using MEDLINE (PubMed), EMBASE and the Cochrane Central Register of Controlled Trials. Study quality was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. The search resulted in 425 papers. After excluding duplicates and selection based on title and abstracts, nine studies were found eligible for further analysis: two randomised controlled trials, and seven observational studies. One randomised controlled trial found a higher polyethylene wear rate in uncemented acetabular components, while the other found no differences. Three out of seven observational studies showed a higher polyethylene wear in uncemented acetabular component fixation; the other four studies did not show any differences in wear rates. The available evidence suggests that a higher annual wear rate may be encountered in uncemented acetabular components as compared to cemented components.

H. C. van der Veen (✉) · J. J. A. M. van Raay
Department of Orthopaedic Surgery, Martini Hospital,
P.O. Box 30.033, 9700 RM, Groningen, The Netherlands
e-mail: hcvanderveen@hotmail.com

H.-P. W. van Jonbergen
Department of Orthopaedic Surgery,
Deventer Hospital, Deventer, The Netherlands

R. W. Poolman
Department of Orthopaedic Surgery, Onze Lieve Vrouwe
Gasthuis, Amsterdam, The Netherlands

S. K. Bulstra
Department of Orthopaedic Surgery, University Medical Center
Groningen, Groningen, The Netherlands

Introduction

Long-term survival in total hip arthroplasty (THA) is mainly determined by aseptic mechanical loosening. In Europe, aseptic loosening is the most common reason for revision in THA, followed by infection and recurrent dislocation [1]. The main factor in the process of this aseptic loosening is a chronic, granulomatous, inflammatory and potential osteolytic response that is induced by implant-derived wear particles [2]. In metal-to-polyethylene bearing couples, these wear particles mainly consist of polyethylene debris derived from the acetabular component. Submicron-sized particles especially lead to macrophage activation and a subsequent release of osteolytic mediators [3]. Polyethylene wear rate and the amount of particles released in a certain time period are directly related to osteolysis. Based on a review of the literature, it was suggested that radiographic wear rates of less than 0.1 mm/year were less likely lead to periprosthetic osteolysis [4].

Several factors may contribute to polyethylene wear, including patient's sex and activity level, femoral head diameter, and also component positioning and the quality of the polyethylene [5–7].

Recent data from the Swedish Hip Arthroplasty Register (SHAR) show a higher rate of revision in uncemented acetabular components due to aseptic loosening, compared to cemented acetabular components [8]. This is in accordance with earlier reports on increased incidence of osteolysis in arthroplasties with uncemented acetabular components [9–11]. We therefore postulated that the wear rate of uncemented acetabular components is higher than the wear rate in cemented components. The purpose of our study was to systematically review the highest available evidence on the wear rate in both types of acetabular component fixation.

Materials and methods

A 'PICOS' was formulated in order to perform a systematic review and meta-analysis of the peer-reviewed literature [12]. We defined our population (P) as patients with primary or secondary osteoarthritis, treated by total hip arthroplasty (THA). The intervention (I) was defined as a THA with a cemented acetabular component. We compared (C) this intervention with a THA with an uncemented component, for the outcome (O) of wear rate (defined as mm/year or overall wear rate) of polyethylene. Study designs (S) were randomised controlled trials or cohort studies comparing both fixation methods of the acetabular component.

Inclusion criteria were specified in advance, and documented in an unpublished protocol. Randomised controlled trials or observational cohort studies comparing patients with cemented polyethylene acetabular components to patients with uncemented, metal-backed acetabular components were included. Furthermore, outcome had to be described as polyethylene wear rate in mm/year, mm^3/year, or as overall wear rate. No language restrictions were used. Excluded were studies that assessed cemented metal-backed components or threaded cups, articulations other than metal-polyethylene, and studies with heterogenic populations and follow-up of less than three years.

Studies were identified using electronic databases searches in MEDLINE (PubMed) (1966 – January 3, 2012), EMBASE (1966 – January 3, 2012) and the Cochrane Central Register of Controlled Trials (January 3 2012). A medical librarian assisted in the search, using the following search terms with Boolean operators: "hip arthroplasty" OR "hip replacement" OR "hip prosthesis" AND (uncemented OR cementless OR "metal backed" OR shell OR cup OR socket OR "press fit") AND (cemented OR cement) AND (polyethylene OR UHMWPE OR LDPE OR HDPE) AND wear. All reference lists of eligible articles were reviewed. Authors of eligible studies were contacted with regard to possible unpublished results or additional statistical data.

The systematic review was performed with adherence to the PRISMA statement [13]. Title and abstract were examined to assess their relevance (Fig. 1). Full articles were retrieved and assessed by two authors, using the prespecified inclusion and exclusion criteria. Disagreements between reviewers were resolved by consensus after discussion with a third reviewer trained in research methodology.

Relevant data regarding study design, study population, intervention and outcome measures (method of wear measurement) were extracted from the text, figures and tables of the articles included.

The quality of the included studies was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [14–16].

Results

A total of 425 papers were identified using the computerised database search. After removing 126 duplicates, 15 articles were included based on title. Abstracts of these articles were assessed, leading to nine eligible articles. Full-text analysis of these nine articles led to the exclusion of one study. The reason for exclusion of this study was: no direct comparison could be made between patients with cemented and uncemented acetabular components, because this was not defined as the primary aim of the study [17]. The authors were contacted, but no additional statistical data were available. After cross-referencing, one article could be added to the final result [18], leading to a total of nine articles eligible for qualitative synthesis (Fig. 1). Due to the heterogeneity of the study designs, study population and type of hip prosthesis, a meta-analysis was not performed. The following review of the literature is therefore descriptive. Studies included two randomised controlled trials [19, 20], and seven retrospective cohort studies [6, 18, 21–25]. The mean follow-up period ranged from five to more than 25 years. A total of 1,271 hips were included with a patient's mean age of 62 years (range 40–72 years). To assess the polyethylene wear of the acetabular component, one paper used radiostereometric analysis (RSA) [19], while the other eight studies used the Livermore method or modifications of the Livermore method. Using this method, on anteroposterior radiographs at follow-up, the shortest diameter of the polyethylene was measured from the centre of the femoral head, and this was compared to the distance at the same location on the initial postoperative radiograph [5]. In six studies, conventional polyethylene was used; three studies [20, 23, 25] used cross-linked polyethylene.

Study characteristics

Onsten and Carlsson used the RSA method to assess the amount of polyethylene wear in a randomised controlled

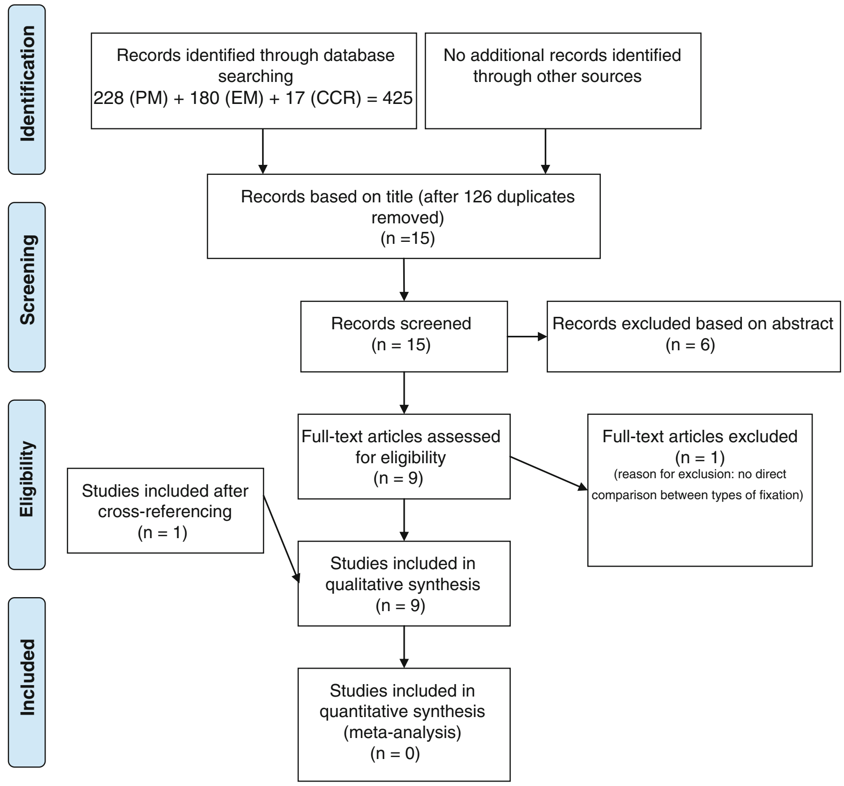

Fig. 1 PRISMA flow diagram. *PM* PubMed; *EM* Embase; *CCR* Cochrane Central Register of Controlled Trials

trial in 95 hips [19]. All patients received a cemented monobloc Charnley stem (DePuy International Ltd, Leeds, UK) with a 22 mm diameter stainless steel head. In 47 hips, a cemented Charnley polyethylene acetabular component was used (DePuy International Ltd, Leeds, UK), while in 48 hips, an uncemented metal-backed Harris-Galante type-I component (Zimmer, Warsaw, Indiana, USA) was used, with additional fixation using two to four screws. At five years of follow-up, no statistically significant differences in annual wear between groups were found (0.09 mm/year vs. 0.10 mm/year). For both cohorts, the type of polyethylene was not further specified, therefore creating a high probability of reporting bias. According to GRADE, the quality of this study is moderate.

McCombe and Williams used a prospective randomised trial to evaluate the annual wear rate in 115 hips [20]. A cemented stem (Exeter, Stryker Australia, Artarmon, Australia) was used in all hips with a 26 mm diameter head. One cohort with 52 hips had an uncemented metal-backed acetabular component (Duraloc 100, DePuy, Mount Waverley, Australia), and the second cohort with 63 hips had a cemented polyethylene acetabular component (Exeter, Stryker Australia). Mean radiological follow-up was 6.5 years, and polyethylene wear was assessed using a digitised Livermore method. In both cohorts, polyethylene had been machined and radiated in air. The uncemented group showed an annual wear rate of 0.15 mm/year, with 0.07 mm/year in the cemented group. This difference was statistically significant ($p<0.0001$). According to GRADE, the quality of this study is high.

A further seven retrospective studies reported the wear rate of uncemented and cemented acetabular components [6, 18, 21–25]. Only three of these studies reported statistical methods; one study observed a lower annual wear rate in cemented acetabular components [25] and two found no difference in wear rate [23, 24]. The remaining four studies did not provide a statistical analysis of the data. Two studies reported a lower wear rate in cemented components as compared to uncemented components [6, 22], and the other two studies found no difference [18, 21]. All these retrospective studies used the Livermore method or modifications thereof. The quality of these retrospective studies according to GRADE is low to very low (Table 1).

Discussion

Only one high quality study was included in our systematic review, demonstrating an increased wear rate in uncemented metal-backed components (Duraloc) versus cemented acetabular components (Exeter) [20]. One moderate quality study showed no difference between cemented acetabular components (Charnley) and uncemented metal-backed components (Harris-Galante type-I) [19]. Three out of seven low to very low quality retrospective studies reported a higher wear rate in uncemented acetabular components [6, 22, 25].

Table 1 Grading of Recommendations Assessment, Development and Evaluation (GRADE) table of studies analysed

A	B	C	D	E	F	G	H	I	J	K	L
Nashed et al. (1995)	O	No	No	No	No	U	24	15		L	(+)
Callaghan et al. (1995)	O	No	No	No	No	D**	104	63		VL	(+)
Onsten et al. (1998)	RCT	Yes#	No	No	No	U	47	48	Cement vs. uncemented: 0.09 vs. 0.10 mm/year (CI95% -0.01–0.03)	M	(+)
Clohisy et al. (2001)	MO	No	No	No	No	U	45	45		L	(+)
Gaffey et al. (2004)	O	No	No	No	No	D**	471	70		VL	(+)
McCombe et al. (2004)	RCT	No	No	No	No	U	63	52	Cement vs. uncemented: 0.07 vs. 0.15 mm/year ($p<0.0001$)	H	+
Hartofilakidis et al. (2009)	O	No	No	No	No	U	50	51		L	(+)
Bjerkholt et al. (2010)	O	No	No	No	No	U	62	30		L	(+)
Kampa et al. (2010)	MO	Yes*	No	No	No	U	15	15		L	(+)

A. Author (publication year)
B. Design
RCT: randomised controlled trial
O: observational
MO: matched case control, observational
C. Limitations
No: no serious limitations
Yes: serious limitations
polyethylene (PE) not specified for both cohorts
* 5 bilateral hips ceramic-PE articulation
D. Inconsistency
No: no serious inconsistency
E. Indirectness
No: no serious indirectness
F. Imprecision
No: no serious imprecision
G. Publication bias
U = undetected
D = detected
** In part same cohorts
H. Number of treated patients (cemented acetabular component)
I. Number of controls (uncemented acetabular component)
J. Effect (annual wear rate mm/year)
K. Quality
H: high
M: moderate
L: low
VL: very low
L. Recommendation
(+): Weak for
+: Strong for

Fixation of acetabular components and polyethylene (PE) wear in patients with primary or secondary osteoarthritis of the hip
Population: patients with primary or secondary osteoarthritis treated with a total hip arthroplasty (THA)
Intervention: THA with a cemented acetabular component
Comparison: THA with an uncemented acetabular component
Outcome: wear rate (mm/year or overall wear rate) of PE

Our systematic review is the first to specifically review the available evidence regarding the possible influence of acetabular component fixation on the wear rate of polyethylene. In order to obtain an evidence-based assessment of the available literature on this subject, we performed our review with adherence to the PRISMA statement and used the GRADE approach. No language restrictions were used, and, if necessary, authors were contacted for unpublished results or additional statistical data. However, our review is limited in that no meta-analysis was performed due to clinical heterogeneity. Furthermore, only two randomised controlled trials were identified; one study used the RSA method, and the other used a digitised Livermore method to assess polyethylene wear [19, 20]. Several confounding factors could have influenced the outcome especially for the retrospective cohort studies. First, authors did not always mention the type of polyethylene used, even in the RCT performed by Onsten and Carlsson [19]. Second, other wear influencing factors, such as cup positioning and patient's activity level, not always were reported. Another limitation is that the mean follow-up in the studies included varied from five years to more than 25 years. This resulted in studies describing the results of obsolete fixation methods of the acetabular component. Both fixation with additional screws and openings in the metal shell are considered risk factors for wear and osteolysis [6, 26].

The Swedish Hip Arthroplasty Register reported a higher rate of revision in uncemented acetabular components due to aseptic loosening, compared to cemented acetabular components, probably resulting from wear-related problems [8]. Increased revision rates were also reported by the Norwegian Arthroplasty Register in the medium-term to long-term follow-up, attributed to wear and osteolysis in modular metal-backed acetabular components. These higher revision rates mostly occurred after seven years [27]. The Finnish Arthroplasty Register showed no important differences in survival rates for aseptic loosening between cemented and uncemented acetabular components. However, further analysis of these registry data showed that numerous revisions of the modular uncemented acetabular components were due to excessive wear of the polyethylene liner [28].

Although registry data do not aim to establish causality [29], increased wear properties of uncemented acetabular components are suggested. This assumed increase in polyethylene wear in uncemented acetabular components can be considered a multifactorial entity. Differences in load transfer due to an absent cement interface, or micromovements of modular polyethylene inserts in metal acetabular components, could lead to this higher wear rate [18, 24]. Poor fit of polyethylene inserts and metal shells due to technical failure of the locking mechanism might also play a role. Furthermore, thinner polyethylene liners used in uncemented sockets, leading to increased contact stresses, may contribute as well. The evidence on this, however, is not straightforward [30–32]. Another theoretical explanation for increased wear rates in press-fit acetabular components could be their less forgiving positioning during implantation, leading to edge loading. This might be prevented in cemented acetabular components, due to a more correctable positioning during implantation.

Two recent systematic reviews [33, 34] comparing cemented and uncemented THA addressed acetabular fixation types in a broader perspective than our review. Pakvis and van Hellemondt reviewed both the clinical and radiological outcome and postulated that the surgeon should choose an established cemented or uncemented acetabular component based on patient characteristics, knowledge, experience and preference [33]. However, Clement and Biant concluded that cemented acetabular fixation may be the gold standard in total hip arthroplasty, based primarily on the lower overall re-operation risk for cemented fixation [34]. In agreement with our findings, both reviews reported an equal or increased articular wear rate with uncemented fixation.

The weakest link in contemporary total hip arthroplasty seems to be the acetabular component. The results of this systematic review suggest a negative influence of uncemented acetabular component fixation on polyethylene wear rate, and are in favour of cementation of the acetabular component. Next to acetabular component cementation, polyethylene itself also plays an important role in improving wear properties. Highly cross-linked polyethylene has shown an excellent medium-term performance [35, 36]. Nowadays, second generation highly cross-linked polyethylenes have been developed with even more wear resistance (eg X3 [Stryker Orthopedics, Mahwah, New Jersey, USA], ArCom XL and E-Poly [Biomet Orthopedics, Warsaw, New Jersey, USA]), showing promising in vitro results [4, 37, 38]. Future research should focus on high quality clinical trials prospectively investigating arthroplasties with cemented acetabular components, in combination with second generation highly cross-linked polyethylene. Because of its ability to address early wear, ideally RSA should be used. However, use of this method is limited because of its relative expense and required expertise. Next to RSA, computer-assisted edge-detection techniques offer improved accuracy in especially the intermediate to long-term follow-up, and are generally more readily available [39].

In conclusion, the results of this systematic review of the available evidence suggest that a higher annual wear rate of polyethylene may be encountered in uncemented acetabular components as compared to cemented components. Future high quality studies should focus on cemented acetabular components combined with second generation highly cross-linked polyethylene.

Acknowledgments We thank Mr. Wieger de Jong, medical librarian at Martini Ziekenhuis Groningen, for assisting in the literature search

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Havelin LI, Fenstad AM, Salomonsson R et al (2009) The Nordic Arthroplasty Register Association: a unique collaboration between 3 national hip arthroplasty registries with 280,201 THRs. Acta Orthop 80:393–401
2. Holt G, Murnaghan C, Reilly J et al (2007) The biology of aseptic osteolysis. Clin Orthop Relat Res 460:240–252
3. Ingham E, Fisher J (2005) The role of macrophages in osteolysis of total joint replacement. Biomaterials 26:1271–1286
4. Dumbleton JH, D'Antonio JA, Manley MT et al (2006) The basis for a second-generation highly cross-linked UHMWPE. Clin Orthop Relat Res 453:265–271
5. Livermore J, Ilstrup D, Morrey B (1990) Effect of femoral head size on wear of the polyethylene acetabular component. J Bone Joint Surg Am 72:518–528
6. Nashed RS, Becker DA, Gustilo RB (1995) Are cementless acetabular components the cause of excess wear and osteolysis in total hip arthroplasty? Clin Orthop Relat Res 317:19–28
7. Little NJ, Busch CA, Gallagher JA et al (2009) Acetabular polyethylene wear and acetabular inclination and femoral offset. Clin Orthop Relat Res 467:2895–2900
8. Hailer NP, Garellick G, Karrholm J (2010) Uncemented and cemented primary total hip arthroplasty in the Swedish Hip Arthroplasty Register. Acta Orthop 81:34–41
9. Duffy P, Sher JL, Partington PF (2004) Premature wear and osteolysis in an HA-coated, uncemented total hip arthroplasty. J Bone Joint Surg Br 86:34–38
10. Nieuwenhuis JJ, Malefijt Jde W, Hendriks JC et al (2005) Unsatisfactory results with the cementless Omnifit acetabular component due to polyethylene and severe osteolysis. Acta Orthop Belg 71:294–302
11. Hallan G, Lie SA, Havelin LI (2006) High wear rates and extensive osteolysis in 3 types of uncemented total hip arthroplasty: a review of the PCA, the Harris Galante and the Profile/Tri-Lock Plus arthroplasties with a minimum of 12 years median follow-up in 96 hips. Acta Orthop 77:575–584
12. Richardson WS, Wilson MC, Nishikawa J et al (1995) The well-built clinical question: a key to evidence-based decisions. ACP J Club 123:A12–A13
13. Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 339:b2535
14. Atkins D, Best D, Briss PA et al (2004) Grading quality of evidence and strength of recommendations. BMJ 328:1490
15. Petrisor BA, Keating J, Schemitsch E (2006) Grading the evidence: levels of evidence and grades of recommendation. Injury 37:321–327
16. Guyatt GH, Oxman AD, Kunz R et al (2008) Going from evidence to recommendations. BMJ 336:1049–1051
17. Digas G, Karrholm J, Thanner J et al (2007) 5-year experience of highly cross-linked polyethylene in cemented and uncemented sockets: two randomized studies using radiostereometric analysis. Acta Orthop 78:746–754
18. Clohisy JC, Harris WH (2001) Matched-pair analysis of cemented and cementless acetabular reconstruction in primary total hip arthroplasty. J Arthroplasty 16:697–705
19. Onsten I, Carlsson AS, Besjakov J (1998) Wear in uncemented porous and cemented polyethylene sockets: a randomised, radiostereometric study. J Bone Joint Surg Br 80:345–350
20. McCombe P, Williams SA (2004) A comparison of polyethylene wear rates between cemented and cementless cups. A prospective, randomised trial. J Bone Joint Surg Br 86:344–349
21. Callaghan JJ, Pedersen DR, Olejniczak JP et al (1995) Radiographic measurement of wear in 5 cohorts of patients observed for 5 to 22 years. Clin Orthop Relat Res 317:14–18
22. Gaffey JL, Callaghan JJ, Pedersen DR et al (2004) Cementless acetabular fixation at fifteen years. A comparison with the same surgeon's results following acetabular fixation with cement. J Bone Joint Surg Am 86-A:257–261
23. Hartofilakidis G, Georgiades G, Babis GC (2009) A comparison of the outcome of cemented all-polyethylene and cementless metal-backed acetabular sockets in primary total hip arthroplasty. J Arthroplasty 24:217–225
24. Bjerkholt H, Hovik O, Reikeras O (2010) Direct comparison of polyethylene wear in cemented and uncemented acetabular cups. J Orthop Traumatol 11:155–158
25. Kampa RJ, Hacker A, Griffiths E et al (2010) In vivo polyethylene wear of bilateral total hip replacements—cemented versus uncemented modular sockets. Hip Int 20:447–452
26. Chen PC, Mead EH, Pinto JG et al (1995) Polyethylene wear debris in modular acetabular prostheses. Clin Orthop Relat Res 317:44–56
27. Hallan G, Dybvik E, Furnes O et al (2010) Metal-backed acetabular components with conventional polyethylene: a review of 9113 primary components with a follow-up of 20 years. J Bone Joint Surg Br 92:196–201
28. Makela KT, Eskelinen A, Pulkkinen P et al (2008) Total hip arthroplasty for primary osteoarthritis in patients fifty-five years of age or older. An analysis of the Finnish arthroplasty registry. J Bone Joint Surg Am 90:2160–2170
29. Graves SE (2010) The value of arthroplasty registry data. Acta Orthop 81:8–9
30. Devane PA, Bourne RB, Rorabeck CH et al (1995) Measurement of polyethylene wear in metal-backed acetabular cups. II. Clinical application. Clin Orthop Relat Res 319:317–326
31. Kurtz SM, Edidin AA, Bartel DL (1997) The role of backside polishing, cup angle, and polyethylene thickness on the contact stresses in metal-backed acetabular components. J Biomech 30:639–642
32. Yamamoto K, Imakiire A, Shishido T et al (2003) Cementless total hip arthroplasty using porous-coated Biomet acetabular cups (Hexloc and Ringloc types). J Orthop Sci 8:657–663
33. Pakvis D, van Hellemondt G, de Visser E et al (2011) Is there evidence for a superior method of socket fixation in hip arthroplasty? A systematic review. Int Orthop 35:1109–1118
34. Clement ND, Biant LC, Breusch SJ (2012) Total hip arthroplasty: to cement or not to cement the acetabular socket? A critical review of the literature. Arch Orthop Trauma Surg 132:411–427
35. Jacobs CA, Christensen CP, Greenwald AS et al (2007) Clinical performance of highly cross-linked polyethylenes in total hip arthroplasty. J Bone Joint Surg Am 89:2779–2786
36. Mutimer J, Devane PA, Adams K et al (2010) Highly crosslinked polyethylene reduces wear in total hip arthroplasty at 5 years. Clin Orthop Relat Res 468:3228–3233
37. Kurtz SM, Mazzucco D, Rimnac CM et al (2006) Anisotropy and oxidative resistance of highly crosslinked UHMWPE after deformation processing by solid-state ram extrusion. Biomaterials 27:24–34
38. Oral E, Malhi AS, Wannomae KK et al (2008) Highly cross-linked ultrahigh molecular weight polyethylene with improved fatigue resistance for total joint arthroplasty: recipient of the 2006 Hap Paul Award. J Arthroplasty 23:1037–1044
39. McCalden RW, Naudie DD, Yuan X et al (2005) Radiographic methods for the assessment of polyethylene wear after total hip arthroplasty. J Bone Joint Surg Am 87:2323–2334