Excessive polyethylene wear and acetabular bone defects from standard use of a hooded acetabular insert in total hip arthroplasty

Davey M. J. M. Gerhardt · Rick J. M. Sanders ·
Enrico de Visser · Job L. C. van Susante

Received: 22 January 2014 / Accepted: 17 March 2014 / Published online: 4 April 2014
© Springer-Verlag Berlin Heidelberg 2014

Abstract

Purpose In total hip arthroplasty (THA) the use of a polyethylene (PE) insert with a hooded rim can be considered to reduce dislocation risks. This benefit has to be balanced against the potential introduction of impingement of the femoral component on this rim. We present a case series of early acetabular revisions for excessive PE wear and acetabular bone defects from overuse of such a hooded rim insert.

Material and methods Twenty-eight patients with 34 consecutive early acetabular revisions were evaluated on failure mechanism. One type of implant was used in all cases. Standard pelvic radiographs and pre-operative CT scans were used to quantify PE wear, implant positioning and acetabular bone defects.

Results An acetabular revision with impaction grafting was performed in all cases with a mean cup survival of ten years (range 1.3–19.3). No concurrent stem revisions were necessary. Overall implant positioning was adequate with a mean cup inclination of 45° (range 39–57) and anteversion of 25° (range eight to 45). The mean PE wear was 0.24 mm/year (range 0.00–1.17). The mean acetabular bone defect on pelvic CT scans was calculated as 352 mm² (range zero to 1107) and 369 mm² (range zero to 1300) in the coronal and transversal planes, respectively. A hooded acetabular insert was retrieved in all cases and profound PE wear, typically from the posterior hooded rim, was encountered.

Conclusion The use of hooded acetabular inserts may be considered to improve implant stability intra-operatively. This case series clearly presents that together with these devices,

component impingement with concordant complications such as accelerated PE wear may be introduced. Standard use of these stabilizing inserts should thus be avoided.

Keywords Osteolysis · Acetabular bone defects · Hip biomechanics · Implant position · Hip arthroplasty · Polyethylene wear

Introduction

Total hip arthroplasty (THA) is one of the most frequently executed orthopaedic procedures [1], inducing relief of pain and improving patient's mobility [2]. Its high success rate and instant hip function improvement go along with increased expectations, however dislocations remain a feared complication by both patients and the surgeon [3]. Hooded rim inserts for the acetabular component are available for several brands and claim to improve stability and reduce dislocation risks. Intra-operatively this hooded rim of the polyethylene (PE) insert can be positioned where the femoral head tends to dislocate during flexion, endorotation and adduction of the hip. Most surgeons choose a posterior approach and these rim inserts are then positioned in a 7 to 11 o'clock position or a 1 to 5 o'clock position for a right or left-sided hip arthroplasty, respectively. Considering their stabilizing effect the use of these devices may thus be appealing to the operating surgeon. On the other hand, it has to be noted that with these hooded inserts a potential new source of prosthetic impingement is introduced by the leveraging effect from the femoral component [4]. This typically accounts for exorotation and extension movements of the hip in otherwise well positioned implants. The forces created between the metallic femoral neck and the acetabular insert rim augment the release of PE debris. Few

Contribution was the same by the first and second authors.

D. M. J. M. Gerhardt · R. J. M. Sanders · E. de Visser ·
J. L. C. van Susante (✉)

Department of Orthopaedics, Rijnstate Hospital, Postbox 9555, 6800
TA Arnhem, The Netherlands
e-mail: jvansusante@rijnstate.nl

studies have reported on this mechanism of enhanced PE debris due to impingement [5–7].

After a relatively small rural hospital had been incorporated into our larger regional teaching hospital a relatively high early acetabular revision rate, due to increased PE wear and pelvic bone defects, was encountered in the series of a retired surgeon. Standard use of hooded rim inserts in otherwise well positioned acetabular components appeared to be an important causative factor for the encountered PE wear and subsequent pelvic bone defects. We report on a consecutive series of these early cup revisions with acetabular bone impaction grafting to emphasize that hooded rim inserts are appealing as stabilizing devices; however, surgeons should be aware that they also have a down-side.

Material and methods

From December 2010 to September 2013 a total of 34 consecutive acetabular revisions were performed and retrospectively analysed for PE wear, pelvic bone defects and failure mechanism. In all cases the same acetabular (Lamella cup with a Lamella hooded Sulene PE-insert; Zimmer, Warsaw, Indiana, USA) and femoral (Emeraude stem and Protasul-S30 head; Zimmer, Warsaw, Indiana, USA) component had been used at the index procedure.

The primary total hip arthroplasties (THAs) were performed by a single surgeon, not involved in the study, through a posterior approach. All acetabular revisions were performed by an experienced hip revision surgeon (>100 implants/year) through a posterior approach using a bone impaction acetabular reconstruction. The indication for acetabular revision was PE wear with or without pelvic bone defects and recurrent dislocation in all cases.

Patient demographics are summarized in Table 1.

Radiographic analysis

Standardized standing anterior-posterior (AP) pelvic radiographs were available in all patients both directly after the primary THA implantation and at their latest follow-up prior to the acetabular revision surgery. Pelvic radiographs were calibrated against the femoral head component with a 28-

mm diameter. Radiographic measurements were executed using Philips Easyvision with an extended Ortho-toolbox (Fig. 1).

The cup inclination was measured as the angle between the horizontal transischial line and the line bisecting the superior and inferior parts of the acetabular metal lamella cup (Fig. 2). In addition, PE wear was measured on the latest pelvic radiograph using an digitalized technique modified from the method described by Livermore et al. [8–10], a widely accepted method for 2D-wear measurement. This technique is based on the principle that normal loading of the polyethylene cup comes up the femoral shaft, along the femoral neck towards the lumbar spine. So it is normal to see slight thinning in the area of the weight bearing as the polyethylene moulds itself. Abnormal loading leads to pressure more lateral, resulting in polyethylene wear on the supero-lateral side, visible as an eccentric position of the femoral head in the cup [11]. PE wear was quantified by fitting a circle, which intersected with the cup edges, in the acetabular component. The centre of this outer circle corresponds with the original centre of rotation of the cup at the time of index surgery. Subsequently, a second circle is generated around the femoral head, whereby the centre of this inner circle represents the new centre of rotation of the cup at the time of latest follow-up. The distance between these two centres of rotation represents the two-dimensional degree of PE wear (Fig. 2).

Pelvic CT scans prior to revision surgery were available in 26 out of 34 cases to visualize acetabular bone defects. These CT scans were also used to determine the anteversion of the acetabular component according to the method described by Mian et al. [12] (Fig. 1a). The cup inclination was re-measured in the coronal plane as the angle between the horizontal interteardrop line and the line bisecting the superior and inferior parts of the acetabular metal lamella cup (Fig. 1c).

The presence and extent of acetabular bony defects were measured in both the coronal and the transversal planes. The area of the acetabular bone defects was calculated in square millimeters by using Ortho-toolbox software (Fig. 1b, d). To improve reproducibility, for each case and in each plane the CT slice representing the largest bone defect was chosen for surface measurements. A maximum bone defect on the transversal or coronal plane of more than 1000 mm² was labelled as severe, between 250 and 1000 mm² was moderate and mild when less than 250 mm².

All CT scans and pelvic radiographs were assessed by two independent observers (DG and RS) and interobserver reliability for the radiographic measurements was calculated.

Correlation and statistical analysis

Data was processed in SPSS (SPSS Inc. Chicago, IL, USA) for statistical analysis. The parameters measurements on AP pelvic radiograph and CT scanning were normally distributed

Table 1 Demographic and revision data

Demographic	THA (N=34) Emeraude/Lamella
Age at surgery, mean (range)	54 (28–72)
Sex (female/male)	15/19
Mean time to revision (years)	10 (1.3–20.4)
Age at revision, mean (range)	64 (39–82)

Fig. 1 CT scans. Cup anteversion (a), the angle between the line bisecting the anterior and posterior part of the metal lamella cup and a perpendicular line towards the horizontal line connecting the posterior portions of the pelvis. Maximal pelvic bone defect in the transversal (b) and coronal (d) planes in square millimetres by using the software Ortho-toolbox. Cup inclination (c), the angle between the horizontal interteardrop line and the line bisecting the superior and inferior parts of the metal lamella cup

on histogram. The entire cohort was divided into two groups with a calculated PE wear rate greater or less than 0.20 mm/year. Subsequently, the correlation (Fisher's exact test and Pearson's correlation coefficient) between wear rates and degree of pelvic bone defects (mild, moderate or severe) was calculated. The interobserver reliability is given as an inter-class correlation coefficient.

Results

Thirty-four acetabular revisions in 28 patients were evaluated. A right-sided acetabular revision was performed in 20 cases

and 19 were male. No femoral component revisions were performed since all stems appeared to be well fixed at time of revision. Pelvic standardized radiographs were available for evaluation in all cases, and 26 cases also had a CT scan available; three CT scans were excluded for measurement of implant positioning and bone defects due to profound artifacts which made proper evaluation impossible. Patients' mean age at time of the primary THA was 54 years (28–72) and the mean acetabular implant survival at time of revision was ten years (1.3–20.4) (Table 1).

Radiographic analysis

A cup inclination of 46° (range 37–65°) was measured on pelvic radiographs. This inclination was confirmed by re-measurement on the available CT scans with 45° (range 39°–57°). The anteversion of the acetabular component was 25° (range 8°–45°) on CT scan. On the pelvic radiographs a total mean PE wear of 2.0 mm (0.0–7.0) was calculated according to the method described (Fig. 2). This overall PE wear could be calculated towards a mean PE wear per year of 0.24 mm (0.0–1.17). The maximum surface of the acetabular bony defect measured 352 mm² (range zero to 1107) in the coronal plane and 369 mm² (range zero to 1300) in the transversal CT plane. These bone defects were categorized as mild (<250 mm²; n=13), moderate (25–1000 mm²; n=7) or severe (>1000 mm²; n=3). In addition, in nine cases bone defects were also encountered on the femoral side in the trochanteric area. Since no stem revision was performed and the primary purpose of this study was to focus on the acetabular side we did not incorporate

Fig. 2 PE-wear measurement on AP pelvic radiograph as the displacement distance between the centres of rotation of the prosthesis cup and head

measurements of these additional bony defects on the femoral side in our evaluation. All radiographic parameters are summarized in Tables 2 and 3. As for PE wear, cases could be divided in a high wear rate group with more than 0.20 mm/year ($n=15$) and a low wear rate group with less than 0.20 mm/year ($n=19$). PE wear rates per year did not correlate with the degree of encountered acetabular bone defects (mild/moderate/severe) with a Pearson correlation coefficient of 0.02 for the transversal plane and 0.164 for the coronal plane ($p=0.12$, Fisher's exact test) (Table 3).

Intra-operative findings

Intra-operative findings at the time of revision surgery were consistent in most cases. At all times a hooded PE insert (Lamella hooded PE-insert; Zimmer, Warsaw, Indiana, USA) had been used and profound PE rim damage had occurred from impingement of the femoral neck on this rim in exorotation and extension (Fig. 3). The acetabular component could be removed relatively easily using the original introduction device. Behind the acetabular component mild to severe bony defects were encountered matching the pre-operative CT scan imaging. After debridement of these bony defects an acetabular reconstruction could be performed with impacted allograft chips followed by a cemented cup revision. Occasionally reinforcement meshes were used to create a contained defect prior to impaction grafting. In nine cases we also encountered bone defects on the femoral side in the trochanter area. These defects were also debrided and grafted with morselized bone allograft; all stems appeared to be well fixed and were left in place.

The inter-observer variability (interclass correlation coefficient) for the radiographic measurements on CT scanning were 0.81, 0.73 and 0.96 ($p<0.001$) for cup anteversion, cup inclination and acetabular bone defects, respectively.

Table 2 Implant positioning, wear characteristics and extent of acetabular bone defects (ABD)

Measurements	THA ($N=34$) Emeraude/Lamella
Parameters on CT scanning ($n=23$)	
- Cup anteversion (range)	25° (8–45°)
- Cup inclination (range)	45° (39–57°)
Mean total area ABD, coronal plane (mm ²)	352 (0–1107)
Mean total area ABD, transversal plane (mm ²)	369 (0–1300)
Parameters on AP pelvic X-ray ($n=34$)	
- Cup inclination (range)	46 (37–65)
- Linear wear (mm), mean	2.0 (0.0–7.0)
- Linear wear rate (mm/year), mean	0.24 (0.00–1.17)

Table 3 Polyethylene wear versus degree of acetabular bone defects (ABD)

Acetabular bone defect	PE-wear <0.2 mm/year ($n=19$)	PE-wear >0.2 mm/year ($n=15$)
Mild: <250 mm ($n=13$)	62 %	40 %
Moderate: 250–1000 mm ($n=7$)	38 %	30 %
Severe >1000 mm ($n=3$)	0 %	30 %

No significant correlation between extent of ABD and polyethylene wear yearly ($n=34$). ABD measured on available CT scans on both coronal and transversal planes ($n=23$). Fisher's exact test P-value 0.12

The inter-observer variability for the AP pelvic radiographic measurements of PE wear and cup inclination were 0.87 and 0.92 ($p<0.001$).

Distribution of individual variables (age, sex, weight, time to revision, component positioning and wear damage) were normal on histogram.

Discussion

An important objective in THA design is to maintain an adequate range of motion (ROM) and stability of the joint after implantation. The availability of modular acetabular components allows the surgeon to choose a plain or hooded acetabular liner for many implant types. These hooded rim options have become commonplace and are still widely used on a routine basis or in cases of intra-operative instability in up to 40 % [13]. The use of a hooded rim is appealing and supports the surgeon's desire to maximize hip stability. Few studies, however, report on disadvantages of the use of these stabilizing devices.

In our study a hooded acetabular PE insert had been used at the primary THA procedure in all cases. Excessive PE wear, typically from the hooded rim, was encountered during revision surgery in 34 consecutive cases (Fig. 3). Only after revising multiple cases with this type of acetabular implant we could conclude that most PE wear originated from impingement on the elevated rim and to a lesser degree from the articulating surface. Pre-operative radiographs revealed an eccentric position of the femoral head within the cup together with acetabular bone defects in a relatively large number of patients, which subsequently triggered our attention. Since the PE insert with hooded rim is not visible on radiographs initially, we felt an inferior PE was most likely to be the causative factor.

On the pre-operative pelvic radiographs a mean polyethylene wear of 2.0 mm was measured at a mean follow-up of ten years. These values were calculated towards a mean wear rate of 0.24 mm per year which is acceptable within the upper range of normality [14]; a wear rate greater than 0.20 mm

Fig. 3 Typical example of intraoperatively encountered polyethylene wear. **a** Acetabular component intraoperative, impingement is visible at the hooded rim. **b** Retrieved acetabular component illustrating the

damage due to neck impingement over the entire polyethylene insert rim. **c** Acetabular metal lamella cup

yearly is considered to be extensive. In our series 19 cases had less and 15 cases more than 0.20 mm wear yearly (Table 3).

The fact that the measured PE wear on the pelvic radiographs (mean 0.24 mm/year) was in the high range, though not extensively high, combined with the absence of a significant correlation between this PE wear and the extent of acetabular bone defects, supports our belief that the vast majority of PE wear in this series originated from impingement on the hooded acetabular insert rim. Besides the profound PE wear from the hooded insert (Fig. 3), it cannot be ignored that PE wear was also present from the eccentric position of the femoral head in the cup and thus from the articulating bearing. The experienced annual wear rate of the articulating PE of 0.24 mm (0.00–1.17) is still relatively high and higher than one would expect for the Sulene PE (ultra-high-molecular-weight polyethylene) used in this insert [15]. It is possible that the leverage of the femoral component on the hooded rim caused forces and peak stresses also on the articulating insert resulting in accelerated wear patterns. Moreover, when impingement on the rim occurs, repetitive motion between the metal shell and PE insert may facilitate the spread of PE wear particles between the PE insert and the inner surface of the acetabular shell [16]. The central fixation opening at the bottom of the metal shell used in this study (Fig. 3c) may facilitate release of PE wear particles behind the acetabular shell, subsequently initiating the observed bony erosions from a macrophage reaction, also referred to as ‘particle disease’ and backside wear. Literature is still inconclusive regarding fixation openings accelerating backside wear [17–19], but there is literature available where this type of opening is recognized as a potential key hole through which PE wear particles can be pressed behind the acetabular component [20, 21]. In more modern acetabular devices these openings are therefore closed with a cap.

Studies on disadvantages of the use of hooded acetabular inserts are scarcely available. Krushell et al., for example, already concluded that when the shell is not malpositioned, a hooded insert does not provide greater ROM or significantly improves stability [22]. Only in cases of acetabular shell malpositioning an optimally oriented hooded insert appeared to improve stability. Besides the potential benefit of improving stability in malpositioned acetabular shells the authors also

described disadvantages such as damage from high loads and impingement on these unsupported polyethylene rims. Furthermore, the authors state that the beneficial effect of a hooded insert is sensitive to the exact positioning of the hooded rim and relocation of the prosthesis is more difficult once dislocated. The prevalence and contributing factors of insert impingement in 162 retrieved components of different THA designs has also been described by Shon et al. [13]. In their series impingement of the polyethylene hooded rim occurred in up to 92 % of the hooded acetabular components.

Given the fact that there is a paucity of literature on potential disadvantages of overuse of hooded inserts our series is exceptional since it reflects the consequence of standard use of these stabilizing implants. However, the retrospective nature of the study and the fact that only 34 consecutive patients are reported on are important limitations. In addition, implant positioning is known to be an important factor in determining a possible (contra)indication for a hooded insert and this could only be determined adequately on CT scanning in 23 out of 34 patients. On the other hand, pelvic radiographs supported implant positioning within acceptable ranges in all patients, which was subsequently confirmed for both planes when CT scanning was available [3, 23–25]. Furthermore, PE wear could only be measured from the actual bearing surface according to a widely used method first described by Livermore et al. [8, 9]; whereas most PE wear appeared to originate from impingement on the hooded rim which was not visible on plain radiographs. In order to assess the total amount of PE wear from the hooded rim all retrieved damaged acetabular cups should have been retained and analysed accordingly. Since the structural mechanism of failure was only recognized after a number of acetabular revisions, we unfortunately did not retrieve all acetabular components to measure the exact polyethylene debris due to rim impingement. For that reason we can only provide data from the recorded intra-operative established hooded rim damage as described in all cases by the operating surgeon.

In conclusion, we report on an exceptional series of early acetabular revisions for accelerated PE wear and pelvic bone defects where standard use of a hooded rim acetabular insert at the index primary THA was identified as causative factor. In well positioned implants surgeons should be aware that

component impingement with concordant complications may be introduced when using these stabilizing devices. Hooded rim inserts are appealing, however their use should be reserved for selected cases where implant malpositioning is suspected. Standard use in primary THA should be avoided.

References

- Clark CR, Heckman JD (2001) Volume versus outcomes in orthopaedic surgery: a proper perspective is paramount. *J Bone Joint Surg Am* 83-A(11):1619–1621
- Battaglia TC, Mulhall KJ, Brown TE, Saleh KJ (2006) Increased surgical volume is associated with lower THA dislocation rates. *Clin Orthop Relat Res* 447:28–33
- Paterno SA, Lachiewicz PF, Kelley SS (1997) The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. *J Bone Joint Surg Am* 79(8):1202–1210
- Scifert CF, Brown TD, Lipman JD (1999) Finite element analysis of a novel design approach to resisting total hip dislocation. *Clin Biomech (Bristol Avon)* 14(10):697–703
- Hall RM, Siney P, Unsworth A, Wroblewski BM (1998) Prevalence of impingement in explanted Charnley acetabular components. *J Orthop Sci* 3(4):204–208
- Isaac GH, Wroblewski BM, Atkinson JR, Dowson D (1992) A tribological study of retrieved hip prostheses. *Clin Orthop Relat Res* 276:115–125
- Yamaguchi M, Akisue T, Bauer TW, Hashimoto Y (2000) The spatial location of impingement in total hip arthroplasty. *J Arthroplasty* 15(3):305–313
- Martell JM, Berdia S (1997) Determination of polyethylene wear in total hip replacements with use of digital radiographs. *J Bone Joint Surg Am* 79(11):1635–1641
- Rahman L, Cobb J, Muirhead-Allwood S (2012) Radiographic methods of wear analysis in total hip arthroplasty. *J Am Acad Orthop Surg* 20(12):735–743
- 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(4):518–528
- Watt I et al (2006) Hip arthroplasty, normal and abnormal imaging findings. Available from: <http://www.radiologyassistant.nl/en/p431c8258e7ac3/hip-arthroplasty.html>. Accessed 28 March 2014
- Mian SW, Truchly G, Pflum FA (1992) Computed tomography measurement of acetabular cup anteversion and retroversion in total hip arthroplasty. *Clin Orthop Relat Res* 276:206–209
- Shon WY, Baldini T, Peterson MG, Wright TM, Salvati EA (2005) Impingement in total hip arthroplasty a study of retrieved acetabular components. *J Arthroplasty* 20(4):427–435
- 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(4):575–584
- van der Veen HC, van Jonbergen HP, Poolman RW, Bulstra SK, van Raay JJ (2013) Is there evidence for accelerated polyethylene wear in uncemented compared to cemented acetabular components? A systematic review of the literature. *Int Orthop* 37(1):9–14
- Usrey MM, Noble PC, Rudner LJ, Conditt MA, Birman MV, Santore RF, Mathis KB (2006) Does neck/liner impingement increase wear of ultrahigh-molecular-weight polyethylene liners? *J Arthroplasty* 21(6 Suppl 2):65–71
- Demmelmeier U, Schraml A, Honle W, Schuh A (2010) Long-term results of the standard Wagner cup. *Int Orthop* 34(1):33–37
- Schmalzried TP, Brown IC, Amstutz HC, Engh CA, Harris WH (1999) The role of acetabular component screw holes and/or screws in the development of pelvic osteolysis. *Proc Inst Mech Eng H* 213(2):147–153
- Yamaguchi M, Bauer TW, Hashimoto Y (1999) Deformation of the acetabular polyethylene liner and the backside gap. *J Arthroplasty* 14(4):464–469
- Farizon F, de Lavison R, Azoulai JJ, Bousquet G (1998) Results with a cementless alumina-coated cup with dual mobility. A twelve-year follow-up study. *Int Orthop* 22(4):219–224
- Nieuwenhuis JJ, Malefijt Jde W, Hendriks JC, Gosens T, Bonnet M (2005) Unsatisfactory results with the cementless Omnifit acetabular component due to polyethylene and severe osteolysis. *Acta Orthop Belg* 71(3):294–302
- Kruehell RJ, Burke DW, Harris WH (1991) Elevated-rim acetabular components. Effect on range of motion and stability in total hip arthroplasty. *J Arthroplasty* 6(Suppl):S53–S58
- Jaramaz B, DiGioia AM 3rd, Blackwell M, Nikou C (1998) Computer assisted measurement of cup placement in total hip replacement. *Clin Orthop Relat Res* 354:70–81
- Seki M, Yuasa N, Ohkuni K (1998) Analysis of optimal range of socket orientations in total hip arthroplasty with use of computer-aided design simulation. *J Orthop Res* 16(4):513–517
- Gallo J, Havranek V, Zapletalova J (2010) Risk factors for accelerated polyethylene wear and osteolysis in ABG I total hip arthroplasty. *Int Orthop* 34(1):19–26