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ORIGINAL PAPER

Occult intra-operative periprosthetic fractures of the acetabulum may affect implant survival

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Abstract

Purpose Occult intra-operative periprosthetic acetabular fracture is a seldom-reported complication of primary total hip arthroplasty (THA). It may potentially be associated with cup instability and implant loosening. The present study aimed to investigate clinical consequences of this complication.

Methods Between 2003 and 2012, a total of 3390 cementless total hip arthroplasties (THA) were performed at our institution. Their medical histories were retrospectively reviewed to identify all patients who received a thin-layer computer tomography (CT) scan of the pelvis including the acetabulum within the first 30 post-operative days. They were evaluated and classified by two radiologists independently with respect to the presence of recent acetabular fractures. All cases with acetabular and periacetabular fractures were included in this study. Electronic medical records were reviewed to assess implant revision. Cup stability was measured with EBRA (Einzel-Bild-Röntgen-Analyse) from plain X-rays.

Results Periprosthetic fractures of the acetabulum were identified in 58 (50.4%) of 115 selected patients. Fractures close to but not including the acetabulum were identified in 45% ($n = 26/58$) of the patients, at the superolateral wall in 17% ($n = 10/58$), at the anterior wall of the acetabulum in 16% ($n = 9/58$) and in 10% ($n = 6/58$) each at the medial wall, and at the posterior wall respectively. One out of these 58 fractures could not be classified. Three of a total of six occult medial wall fractures had to be revised, and another two showed a high implant migration. The highest cup migration values however were found after fractures of the superolateral wall. Incomplete column fractures did not influence implant survival.

Conclusion Central wall acetabular fractures, although unrecognized intra- and post-operatively may impair implant survival after THA.

Keywords Periprosthetic fractures · Acetabular fractures · Cup migration · Total hip arthroplasty · Total hip replacement · Einzel-Bild-Röntgen-Analyse (EBRA)

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Introduction

Periprosthetic fractures are a serious and challenging complication, potentially compromising implant stability. The incidence of intra-operative periprosthetic femoral fractures has been reported to be between 0.1–1% for cemented [1, 2] and nearly 5% for uncemented primary total hip arthroplasties [2–7] (THA). In contrast, periprosthetic acetabular fractures were seldom in the focus of articles and were reported to be rare complications.

Following the current literature, the prevalence of obvious intra-operative periprosthetic acetabular fractures after uncemented cup fixation is as low as 0.4% [8], and only few publications suggest a treatment algorithm [9–14]. The use of cementless acetabular components in THA has become more common during the past two decades [2, 15]. Occasionally, acetabular fractures are diagnosed because patients report groin pain weeks after surgery [12]. Previous studies suspected that the widespread use of cementless press-fit acetabular cups might lead to a much higher number of fractures than is clinically detectable [12]. Recently, Hasegawa et al. reported in their study a prevalence of intra-operative occult periprosthetic acetabular fractures after press-fit cup impactions of 8.4% [14].

As the function of an implant relies heavily on a stable bone-prosthesis interface, a fracture that disrupts this interface may have grave implications of the function and survival of the component [16]. To the best of our knowledge, to date there is no study investigating the effect of occult periprosthetic acetabular fractures on stability and survival of the implants [14, 17].

The purpose of the study was to estimate the influence of occult periprosthetic fractures on the stability, survival, and migration of acetabular components.

Materials and methods

The study was approved by the local ethics committee (Medical University of Innsbruck, Austria; number UN5059).

We defined occult acetabular fractures as acetabular fractures not recognized by the surgeon during and after operation, either because they are not detectable during operation, clinically, or in post-operative X-rays, or difficult to detect without particular awareness to the problem. We retrospectively reviewed all patients with a cementless primary hip arthroplasty, performed between 2003 and 2012, who had a computer tomography (CT) scan within the first 30 post-operative days after implantation of a cementless primary THA. One hundred fifty nine out of 3390 primary uncemented THAs performed within the chosen period were identified. Only thin-layer CT scans with the acetabulum completely shown were included. Forty-four of the 159 patients did not fulfill this criterion and had to be excluded. Of the remaining 115 patients, 76 showed an acetabular or periacetabular fracture. Allocation diagnoses for these 76 CT scans were suspected femoral fractures ($n = 4$), suspected acetabular fracture ($n = 1$), suspected fractures without further specification ($n = 14$), abdominal symptoms ($n = 19$), suspected bleeding ($n = 19$), infection ($n = 4$), or remaining postoperative pain after THA ($n = 15$). Eighteen patients had a pelvic fracture apart from the acetabulum and were excluded from further analysis (ischial fractures ($n = 10$), fractures of the inferior pubic ramus ($n = 3$), superior pubic ramus ($n = 3$), and iliac wing fractures ($n = 2$). All remaining 58 patients had an isolated periprosthetic acetabular or periacetabular fracture which did the surgeon not detect intra-operatively. Patient flowchart is shown as Fig. 1.

Prosthetic stability and cup migration were assessed respectively with EBRA (German: Einzel-Bild-Röntgen-Analyse) [18] from plain X-rays. EBRA is a well-established method that evaluates standard anterior-posterior radiographs without requiring additional means at exposure (e.g., ball markers). Simulating the spatial situation, it computes parameters of longitudinal and transverse migration of prosthetic cup and femoral head. A comparability algorithm using a grid of transverse and longitudinal tangents of the pelvis contour divides serial radiographs into sets of comparable ones. Migration is measured only between comparable radiographs. The 95% confidence limits for EBRA results are 1.0 mm for longitudinal and 0.8 mm for transverse migration [18].

In our department, we follow patients with radiographs routinely before discharge, six weeks after surgery and 12 months post-operative. We perform additional radiographs if the patient has any complains with the THA. All radiographs were taken with the same technique (anterior-posterior (AP) radiographs; patient standing in upright position and full weight-bearing) at our Department for Radiology. For our EBRA investigation, a minimum of three radiographs per patient and a minimum of radiological follow-up, up to six months was required for this analysis. Migration could be determined in 27 of the 58 patients. Migration analysis was done with EBRA [18] by one independent investigator who was not involved in the surgeries and the postoperative treatment of the patients.

Radiological analysis for detection of acetabular fractures was done by two senior radiologists independently, on the basis of post-operative thin-layer CT scans. They classified the thin-layer CT scans according to the AO classification [19] and the acetabular fracture classification by Judet and Letournel [20–22]. The mentioned classifications are prescribed in previous publications [19, 20, 22]. As both classification systems deal with severe trauma, column fractures are meant to be complete fractures with loss of continuity. In this sense, both classifications turned out to be not adequate for our purposes. Therefore, we assigned incomplete column

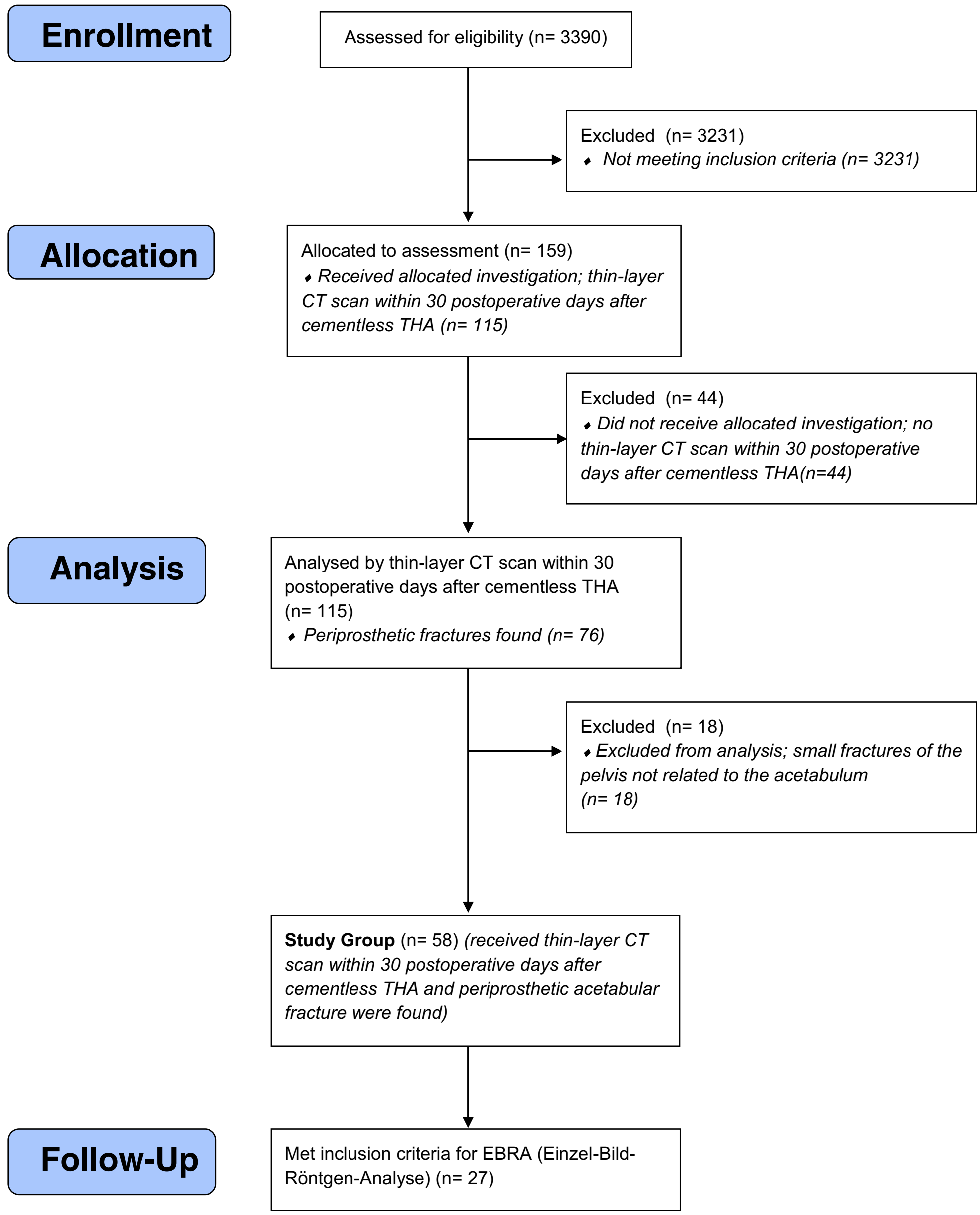

Fig. 1 CONSORT guidelines patient flow diagram

fractures to the categories originally intended for complete loss of continuity only. The location of these fractures, however, is exactly as described in the original articles [19, 20, 22]. During this evaluation process, Hasegawa et al. [14] published a classification for periprosthetic acetabular fractures, which turned out to be very useful for our patient collective. As a consequence, one of the present authors classified the acetabular fractures according to Hasegawa et al. [14] using the detailed fracture descriptions of both radiologists. Hasegawa et al. describe five locations of occult acetabular fractures. These locations are named as (1) medial wall (H1), (2) posterior wall (H2), (3) superolateral wall (H3), (4) anterior wall fractures (H4), and (5) fractures in other locations (H5) [14].

The statistical analyses were performed from an independent statistician. Mean, median, range, and standard deviation were calculated for the different measurement parameters. For the analysis, Access and Excel (Microsoft Office Professional Plus 2010, Redmond, US-WA) as well as Graph Pad Prism (Version 7.0, GraphPad Software, Inc., La Jolla, US-CA) were used.

Results

In our study, occult fractures of the acetabulum after THA were found in 58 (50.4%) out of 115 highly selected patients, 22 men and 36 women. Mean age at surgery was 67.5 years (SD ± 11.6), mean BMI was 26 kg/m^2 (SD ± 5.4), and mean surgery time was 74 minutes (SD ± 39). Average time between surgery and thin-layer CT scan was ten days (SD ± 8.4). The median follow-up was 12 months (range 0–138).

Two different surgical approaches were used. In 22 patients, a lateral transgluteal and in 36 patients a direct-anterior approach [23] was performed. Pre-operative diagnoses included osteoarthritis ($n = 45$), fractures of the femoral neck ($n = 5$), avascular necrosis of the femoral head ($n = 3$), osteoarthritis after hip dysplasia ($n = 3$), fracture of the acetabulum ($n = 1$), and pathological femoral neck fracture ($n = 1$). In nine patients, surgery was performed in a lateral position; the majority of interventions was done in a supine position ($n = 49$). All assessed patients underwent a primary cementless hip arthroplasty. Patient demographics are summarized in Table 1.

Five different types of cup components were inserted:

a) Peripheral self-locking Trident® PSL (Stryker Howmedica Osteonics; $n = 16$) with a 1.8 mm peripheral press-fit built into the shell as marked (e.g., 52 mm = 53.8 mm) [24]. Ten Trident® PSL cups were over reamed of 1 mm (this means an under reaming of 0.8 mm of the real cup size), five cups were reamed line-to-line, and one was under reamed with 2 mm.
b) True hemispherical Duraloc® cups (DePuy-Synthes Warsaw IN, USA; $n = 20$). Under reaming of 1 to 2 mm is recommended by the manufacturer, preferably 1 mm until cup size of 52 mm and 2 mm for bigger cups [25]. Eleven Duraloc® cups were under reamed with 2 mm, three cups were line-to-line reamed and in five patients, this information was not available.
c) Trident® Hemispherical cups (Stryker Howmedica Osteonics; $n = 13$). Under reaming by 1 to 2 mm of the actual Trident® Hemispherical shell size is recommended to achieve interference fit [26]. Eight Trident® Hemispherical cups were reamed line-to-line, four cups were over reamed with 1 mm, and one cup was under reamed with 2 mm.
d) Trilogy® cups (Zimmer-Biomet; Warsaw, IN, USA; $n = 8$). An appropriate undersized reamer is recommended to prepare the acetabulum, if a press-fit condition is desired [27]. All Triology® cups were reamed line-to-line.
e) Allofit® elliptical cup (Zimmer-Biomet; Warsaw, IN, USA; $n = 1$). The size of the definitive shell should match the last reamer used; the excess of 2 mm has been taken into account [28]. The Allofit® cup was reamed line-to-line.

Table 1 Patient demographics of the study group

Number of patients	Female	36
	Male	22
	Total	58
Median age (range) [years]		67.5 (40–89)
BMI (range)		26 (17–39)
Operation time (range) [min]		74 (40–253)
Surgical approach	Direct anterior	36
	Lateral transgluteal	22
Pre-operative diagnosis	Osteoarthritis	45
	Fractures of femoral neck	5
	Avascular necrosis of the femoral head	3
	Osteoarthritis after hip dysplasia	3
	Fractures of the acetabulum	1
	Pathological femoral neck fracture	1
Surgical position	Supine	49
	Lateral	9
Acetabular cups	Duraloc®	20
	Trident® PSL	16
	Trident® Hemispherical	13
	Trilogy®	8
	Allofit®	1

Following the classification as suggested by Hasegawa et al. [14], acetabular fractures outside of the acetabulum but close to it (other locations; H5) were seen in 45% (n = 26/58), at the superolateral wall (H3; Fig. 2) in 17% (n = 10/58), at the anterior wall of the acetabulum (H4) in 16% (n = 9/58), in 10% (n = 6/58) each at the medial wall (H1) (Fig. 3), and the posterior wall (H2) respectively. One fracture could not be classified according to Hasegawa et al. classification.

Following the AO classification [19], 52% (n = 30/58) of the acetabular fractures in our study group were classified as 62A2, 33% (n = 19/58) as 62A3, 7% (n = 4/58) were 62A2 and 62A3, 7% (n = 4/58) of the fractures could not be classified by the AO classification. In 2% (n = 1/58), a 62A1 fracture was found. In 76% (n = 44/58) of the fractures, a type a (posterior wall fractures), 5% (n = 3/58) c (anterior wall fractures), 5% (n = 3/58) e (transverse column fractures), 5% (n = 3/58) h (T-style fractures), 2% (n = 2/58) i (anterior column posterior hemitransverse fracture), and 7% (n = 4/58) could not be classified by the Letournel and Judet classification [20–22] could be classified. Details were shown in Table 2.

In the present study group, 27 patients met the inclusion criteria for migration analysis with EBRA [18]. A median of four (range 3–10) investigated plain X-rays was assessed for each patient. The median radiological follow-up was 25 months (range 8–138 months). Median cup inclination was 38° (range 24–57°), and median cup anteversion was 19° (range 19–35°). Twelve patients out of 27 showed migration higher than 2 mm (range 2.0–6.6) within two years. The highest cup migration was shown in one patient with a superolateral wall fracture (H3) with a cup migration of more than 6 mm within six months postoperatively. This cup was not revised in the course of the radiological follow-up of eight years (see Fig. 4; H3 at 60 months). In six cases, migration was above 3 mm within the first two post-operative years. Migration curves of all cups are shown in Fig. 4.

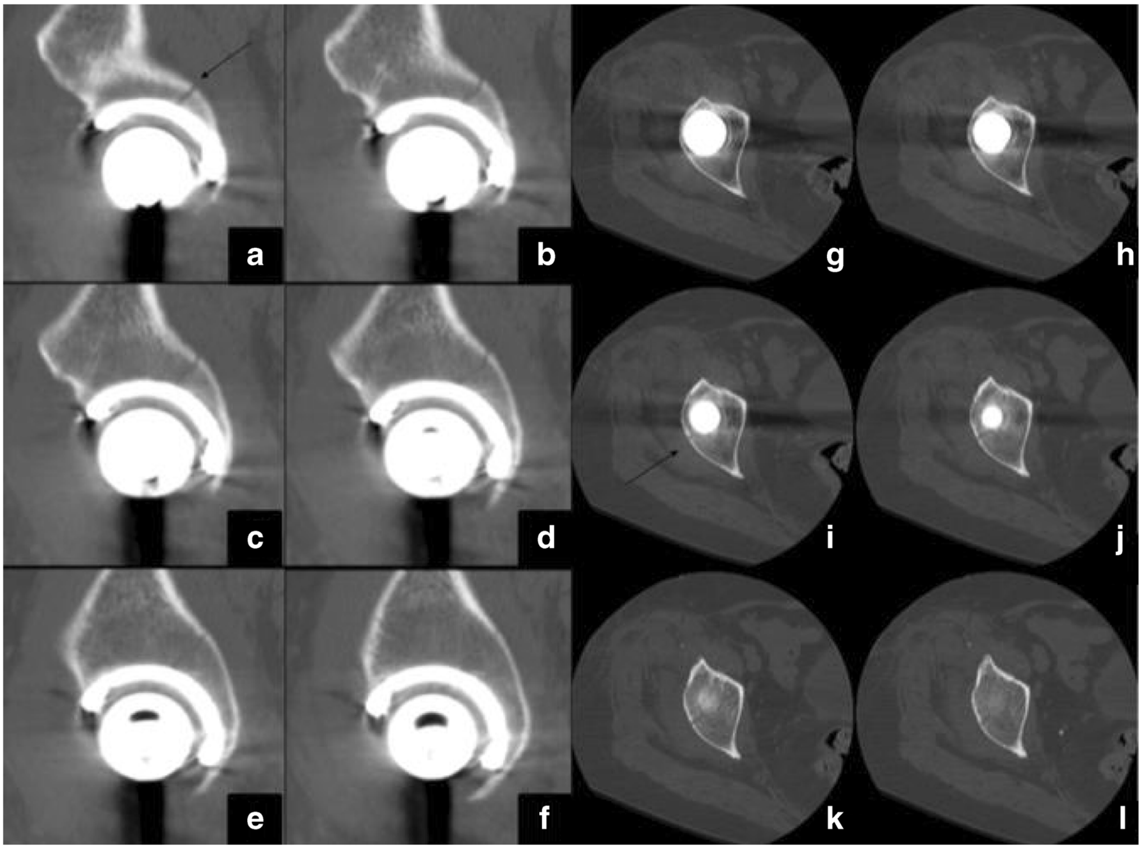

Fig. 2 We defined occult periprosthetic acetabular fractures as those that could be confirmed on a post-operative CT scan but were not seen in intra-operative or found on post-operative radiographs. The post-operative CT scan shows a periprosthetic acetabular fracture of the superomedial wall on coronal (**a**–**f**) and axial images (**g**–**l**). The arrow on the images **a** and **i** shows a periprosthetic fracture of the superolateral wall of the acetabulum

Revision surgery was done in eight patients (1.4%), in four cases for early post-operative infection (2 weeks, 2 months, 10 months, and 23 months after the index operation respectively), in two patients for aseptic loosening and cup migration after 16 and 24 months respectively, and in two patients for fractures of the acetabulum with protrusion and obvious cup loosening.

In our study group, patients with fractures of the medial wall (H1), according to the classification by Hasegawa et al. [14], were more likely to be revised than the other patients with periprosthetic acetabular fractures. Out of six medial wall (H1) fracture cases, three had to be revised for aseptic loosening. Two of them underwent revision surgery within two weeks post-operatively, and one patient had to be revised after 24 months because of cup loosening. Further, two patients showed high values of cup migration with a subsidence assessed with EBRA of 2.7 mm within the first post-operative year in one patient and 4.8 mm within ten months in a second

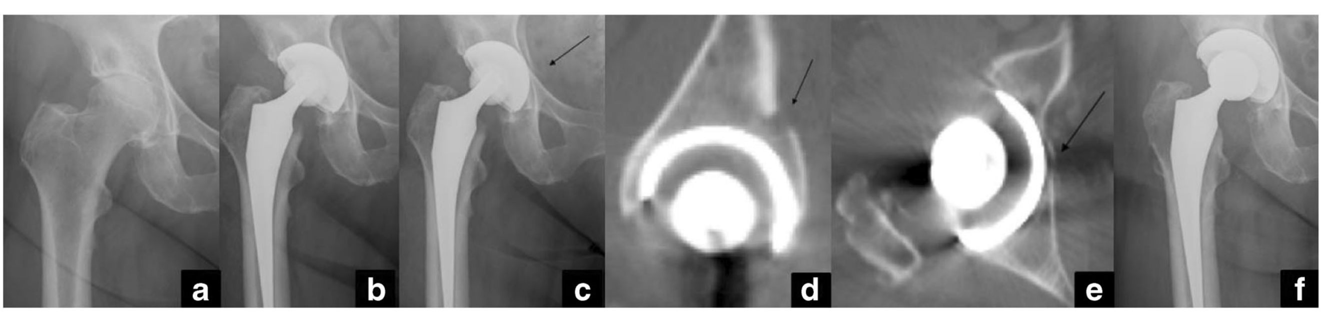

Fig. 3 The diagram shows an occult fracture in the medial wall. We reconstituted pre- and post-operative X-rays and CT images to pre-operative showing a osteoarthritis of the hip (**a**), 6 weeks post-operative plain X-ray (**b**), 8 weeks post-operative plain X-ray (**c**), 8 weeks post-operative CT scan showing a medial wall fracture of the acetabulum (**c**, **d**), and a 1 week post-operative X-ray after revised cup component (**f**)

Table 2 Frequency of fracture patterns and classification of all patients ($n = 58$) analyzed according to the three abovementioned classification systems. In parentheses, the percentage is reported. *NC* not classified. AO and Letournel classifications contain small and incomplete column fractures in the categories originally intended for complete column fractures

AO Classification					
62A1	62A2	62A3	62A2 and 62A3		**NC**
1 (2%)	30 (52%)	19 (33%)	4 (7%)		4 (7%)
Hasegawa classification					
Medial wall	Posterior wall	Superolateral wall	Anterior wall	Other location	NC
6 (10%)	6 (10%)	10 (17%)	9 (16%)	26 (45%)	1 (2%)
Letournel and Judet classification					
a (Aosterior wall)	c (Anterior wall)	e (Transverse column)	h (T-style fracture)	i (Anterior column and posterior hemi-transverse)	NC
44 (76%)	3 (5%)	3 (5%)	3 (5%)	1 (2%)	4 (7%)

patient. The first mentioned case seemed to have stabilized in the further course and showed no more migration until last clinical and radiological follow-up four years after index operation. The second patient underwent revision surgery of the cup. In another patient with a medial wall fracture, the cup was stable and showed no migration until last clinical and radiological follow-up until five years post-operatively.

The highest cup migration values were shown in one patient with a fracture of the superolateral wall (H3). This patient showed a cup migration of more than 6 mm within six months but a subsequently stable cup situation without further migration until last radiological follow-up after eight years.

Discussion

The purpose of the present study was to estimate the influence of occult periprosthetic fractures on the stability, survival, and migration of acetabular components after primary uncemented

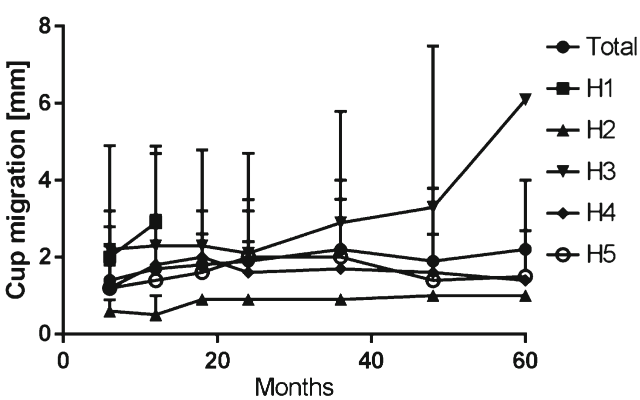

Fig. 4 Mean cup migration and standard deviation of all patients of the different Hasegawa classification groups: (H1) medial wall, (H2) posterior wall, (H3) superolateral wall, (H4) anterior wall, and (H5) other locations during the a median radiological follow-up period of 12 months (range 0–138 months). Observation of H1 is censored due to the need of revision. Severe migration is shown in one single H3 patient > 6 mm cup migration within 6 months but a stabile cup till a radiological follow-up of 8 years

THA. Occult periprosthetic acetabular fractures might be a source of unexplained pain after THA, not typically recognized by intra-operative findings or post-operative radiographs [14].

Ricioli et al. reported in their study a prevalence of 5.39% intra-operative periprosthetic fractures, they however did not differentiate between acetabular and femoral fractures [7]. Intra-operative periprosthetic fractures of the acetabulum were regarded as a rare complication of primary total hip arthroplasty occurring during acetabular exposure, hip dislocation, reaming of the acetabulum, or impaction of the acetabular component [7, 8, 29]. Already in 1997, Callaghan saw the occurrence and recognition of periprosthetic fractures of the acetabulum, as well as those of the femur, on the rise, especially during the intra-operative and early post-operative periods, because of the need for press-fit stability of total hip prostheses inserted without cement [29]. In a retrospective study of 7121 primary hip arthroplasties, Haidukewych et al. reported a prevalence of fractures only in patients undergoing acetabular component fixation without cement of 0.4%. In all cases, the fractures were noted during the operation, 76% of them during the impaction of the acetabular component [8]. The authors already suspected a much higher true prevalence of these acetabular fractures [8]. A recent retrospective study from Hasegawa et al. revealed a much higher rate of occult periprosthetic acetabular fractures comparing pre-operative and post-operative CT scans [14]. They found fractures in 41 of 585 (8.4%) hips [14]. In the present study, we found post-operative acetabular fractures after cementless THA in 58 out of 115 highly selected patients (50.4%), undergoing a thin-layer CT scan of the pelvis within 30 days post-operatively. Although the present study design does not allow estimating the incidence of occult acetabular fractures, our data support the finding of Hasegawa et al. and suggest that the rate of intraoperative acetabular fractures is much higher than previously assumed. The fractures found in the present study showed a high variation of location and size, all potentially affecting implant stability.

The most widely used classification system of acetabular defects and periprosthetic fractures of the acetabulum associated with THA is that by Paprosky [30]. Davidson et al. have offered a simplified version of the Paprosky classification [31]. However, they have restricted this to intra-operative fractures only, hence, the equivalent of the Paprosky types 1 and 2: (1) undisplaced fracture not compromising the stability of the reconstruction, (2) undisplaced fracture which may compromise the stability of the reconstruction, and (3) displaced fracture [31]. The fracture classification system of Letournel and Judet was intended to deal with severe fractures of the acetabulum, where type II, III, and IV mean complete separation of one or both columns [20, 22]. Also, the AO classification is basically describing the same fracture types [19]. Lacking another classification, the present study was designed to apply these well-known classifications. However, we found these established classifications for traumatic acetabular fractures or for revisions of no avail for our patient series, as occult periprosthetic fractures do not affect an entire pelvic column or major bony defect of the acetabulum [19, 20, 30]. When data evaluation of the present study was done, Hasegawa et al. published a classification that in contrast seemed very useful for our analysis and was therefore included in our methodology. In the study by Hasegawa et al., the superolateral wall was the most frequent location for occult fractures of the acetabulum [14]. The authors however did not draw any conclusions regarding cup stability, migration, or loosening.

In our present study, only central fractures (medial wall; H1) showed premature loosening. These fractures were also recognizable on plain X-rays. Post-operative CT controls for detection of periprosthetic acetabular fractures therefore seem to be unnecessary due to the lack of clinical consequences. In the study of Hasegawa et al., all patients with occult fractures showed stable bony ingrowth at final follow-up after 12 months without any additional surgical intervention [14]. This study however provides only short-term information on cup stability after occult periprosthetic acetabular fractures and migration analysis, able to predict of long-term implant stability, was not performed. Early loosening and revision might be more frequent in association with certain fracture patterns. In contrast to earlier studies, we were able to follow the further fate of cup components and measure migration using the EBRA method [18]. The high predictability of survival of acetabular components based on migration measured with RSA or EBRA is based on the assumption that primary stability of the implant is a precondition for bony ingrowth. An occult acetabular fracture may be an unrecognized reason for lacking ingrowth. In addition, if initial cup stability is not obtained, osseous ingrowth is not likely. This possible source of implant failure was almost neglected in the past.

The present study has several limitations, such as the retrospective methodology, and the selection bias of our study group, and thus the true prevalence of these fractures could not be addressed. We did not investigate the role of other factors, which may lead to failure of the THA, such as host-related factors, comorbidities, under reaming, cup size, etc. Without considering these factors, we cannot definitely report that the bad outcomes are associated with occult periprosthetic acetabular fractures. Another limitation is that only 27 patients fulfilled the criteria for migration analysis with EBRA, this may lead to another selection bias limiting the interpretation of the study results. In addition, the study might have suffered from the fact that in our study, there was no control group and no statistical analysis comparing to our study group. Therefore, we cannot report correlations between our study group and any control group.

Overall, it can be concluded that occult periprosthetic acetabular fractures of the medial wall occurring during cementless cup implantation showed an increased rate of cup revision and higher cup migration compared to acetabular fractures at other locations. At the moment, our data do not allow to estimate the proportion of loose cups due to this mechanism leading to primary instability of the acetabular component. It however seems to be much higher than previously assumed and one can speculate that this rate differs for the various acetabular component designs, the amount of under reaming and the quality of bone stock. Our data also suggest that medial wall fractures may be associated with a higher amount of cup migration and loosening, and those patients should therefore be monitored closely. Further observational studies are necessary to identify the consequences of periprosthetic acetabular fractures in the long term.

Compliance with ethical standards

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

Ethical approval The local ethics committee approved the study.

Informed consent Informed consent was obtained from all individual participants included in the study.

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