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ORIGINAL PAPER

Prevalence of dysplasia as the source of worse outcome in young female patients after hip resurfacing arthroplasty

Thomas P. Gross · Fei Liu

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Abstract
Purpose Smaller femoral component size has been implicated as underlying the risk factor that explains the higher failure rate in women who have a hip resurfacing arthroplasty (HRA). We suspect that the diagnosis of dysplasia may be a more important causative risk factor than either small component size or female gender.
Methods From January 2002 to July 2008, a total of 1,216 HRA cases, 1,082 with the primary diagnosis of osteoarthritis and 134 with dysplasia, were included in this study. Of them, 867 cases were performed in men and 349 performed in women. The average femoral component size was 51±4 mm. Cox proportional hazard regression models were used to evaluate the significance of each variable and determine the causative risk factors for failure.
Results The average follow-up was 5±2 years. Thirty-nine cases failed (20 in men vs. 19 in women). The failure rate for the whole group was 3.2% (2.3% in men vs. 5.4% in women; $P=0.01$). Dysplasia ($P=0.05$) was identified as the only significant risk factor in our multi-variable analysis; small femoral component size ($P=0.09$) and gender ($P=0.76$) were not significant risk factors. Women with the primary diagnosis of dysplasia had a survivorship rate of only 75% compared to 93% for the entire group at eight-year follow-up post-operatively.
Conclusions In our study, we found that the high incidence of dysplasia in young women undergoing HRA was the reason that women had a higher failure rate after HRA. In dysplasia, 70% of failures were due to acetabular problems, of which 50% were due to failure of fixation and 20% due to adverse wear.

T. P. Gross · F. Liu (✉)
Midlands Orthopaedics, p.a.,
1910 Blanding St,
Columbia, SC 29201, USA
e-mail: feilresearch@gmail.com

Introduction

Hip resurfacing arthroplasty (HRA) has gained renewed interest since the application of metal-on-metal bearing surfaces in the 1990s [1–3]. The procedure was revisited to address the high failure rates in young patients with standard stemmed total hip arthroplasty (THA). Many reports have documented promising mid-term outcomes of this surgical technique. In an effort to improve the results of HRA, various factors have been identified that may lead to a higher risk of failure. Initially, in a small group of 119 patients, *Beaule* identified femoral head cysts, previous hip surgery, low patient weight (<82 kg) and high activity (UCLA score ≥6) as risk factors for HRA. This was called the surface arthroplasty risk index (SARI) [4]. Soon, other studies found that older age and female gender were associated with more complications, particularly femoral neck fracture [2, 5]. Recently two studies have implicated smaller component size, rather than low weight or female gender, as the factors truly responsible for higher failure rates in HRA [6, 7] .

Dysplasia is well known to be a high-risk group in stemmed THA [8, 9]. The primary causes of failure have been instability and failure of socket fixation. Theoretically, larger bearings in HRA should decrease the problem of instability, but limited fixation options with acetabular components in HRA may increase the socket fixation problems. In addition, adverse wear has been associated with dysplasia in HRA in one study [10]. Dysplasia, female gender and small component size have all been identified as risk factors for HRA [6, 11]. These factors are interrelated: dysplasia is more common in young women presenting for HRA, while small component size is more common in women and in dysplastic patients. Our hypothesis is that difficulty in gaining component fixation in deformed dysplastic sockets is the primary risk factor for HRA,

underlying the reported risk factors of female gender and small component size. The purpose of this study was to compare the clinical and radiological outcomes of a group of osteoarthritis (OA) and dysplasia patients from our database in order to determine whether our hypothesis is correct.

Materials and methods

This study was approved by the institutional review board (IRB). From January 2002 to July 2008, the senior author (T.P.G.) performed 1,374 metal-on-metal HRAs. We selected all patients with the preoperative diagnosis of OA (1,082 cases) and compared them to all cases with a diagnosis of dysplasia (134 cases). The 158 hips with other diagnoses were excluded for this analysis. In total 1,216 HRA cases in 1,041 patients were included in this study. Corin Cormet 2000 hip resurfacing prostheses (Corin Group PLC, Cotswolds, UK) were used in 280 cases, Biomet Recap/Magnum hybrid hip resurfacing prostheses (Biomet, Warsaw, IN, USA) in 668 cases and Biomet Recap/Magnum fully porous coated hip resurfacing prostheses (Biomet, Warsaw, IN, USA) in 268 cases.

The Corin Cormet 2000 acetabular device has a dual plasma spray coating of titanium and hydroxyl apatite. The Biomet Magnum acetabular component has only a titanium plasma spray layer that is thicker. The arc of coverage in both components varies with implant size and is similar. Both are high carbon cast cobalt chrome with similar surface finishes, except that the Corin device is heat-treated. The undersurface of the Corin femoral device is a chamfer cylinder, while the Biomet femoral recap is a hemisphere on a cylinder. The Corin stem is tapered, while the Recap stem is cylindrical. Both cemented femoral components are grit blasted. The uncemented Recap also has a layer of titanium plasma spray on the component undersurface (but not the stem), similar to the Magnum acetabular component.

The first group of implants in this study were hybrid Corin Cormet 2000 implants as part of a US Food and Drug Administration (FDA) Investigational Device Exemption (IDE) study that the senior author led [12]. However, because the senior author wished to use an uncemented system and Corin was unable to provide this, he embarked on a development project with Biomet. The Biomet Recap / Magnum system became available as a hybrid system in 2005 and finally as an uncemented system in 2007 [13]. We now exclusively use uncemented components in all cases.

There were 867 (71%) cases implanted in 740 men and 349 (29%) cases implanted in 301 women. In men, the primary diagnosis was dysplasia in 38/867 (4%) cases and OA in 829/867 (96%) cases; in women, the diagnosis was dysplasia in 96/349 (28%) cases and OA in 253/349 (72%) cases ($P<0.001$). Of all dysplasia patients in our series of young patients presenting for HRA 72% (96/134) were women, while men comprised only 29% of all cases. The average age for the whole group was 51±7 years (range 20–78), the average body mass index was 27±4 (range 17–55).

All operations were performed using the posterior approach. Over time, the approach was modified using minimally invasive techniques which were previously described [14]. All patients with Crowe I and II dysplasia were treated with a HRA. No structural bone grafts were used. To gain maximum component coverage, often an attempt was made to deepen the socket. In these cases, we drilled and measured the medial wall thickness with a depth gauge to avoid decreasing the medial wall thickness below 6 mm. The rare patients that we encountered with Crowe III and IV dysplasia were treated with stemmed THA and were therefore not included in this study. Often in dysplasia cases, the acetabular component was uncovered in the anterior-superior quadrant. We accepted up to 30% of lack of coverage, but did not document the actual amount intraoperatively. No supplemental fixation was available for the acetabular component at the time of this study.

The average American Society of Anesthesiologists (ASA) score was 2±1 (range 1–4). The average femoral component size was 51±4 mm (range 40–64 mm) and the average acetabular component size was 57±4 mm (range 46–68 mm). There were 205 (17%) cases with the femoral component size <48 mm in the entire group. There were ten (1.2%) cases in men and 195 (55.9%) cases in women. The average size of femoral component was 46±2.5 mm (range 40–56 mm) for the women and 53±2.9 mm (range 40–64 mm) for the men ($P<0.001$); the average size of femoral component was 48±3.6 mm (range 40–58 mm) for the dysplasia patients and 51±3.9 mm (range 44–64 mm) for the OA patients ($P<0.001$). The average operation time was 113±18 minutes (range 76–278 minutes), and the average hospital stay was 3±1 days (range 1–11 days). The average estimated blood loss was 245±120 cc (range 50–1000 cc). The cell saver was used in 98 cases, returning an average of 125±69 cc (range 50–440 cc); 375 cc of autologous blood was used in one bilateral patient (2/1216, 0.2%). Post-operative follow-ups were requested at six weeks, one year, two years and every other year thereafter. Local patients were seen in our office. Out-of-state patients were requested to return to our office for follow-up, but often they submitted their questionnaires online, by mail or email, or had a phone interview. The physical examination data were obtained from a local physical therapist and radiographs were mailed to us. We defined failures as all cases that were revised either elsewhere or by us. We analysed the data using two methods: comparing failure rates and also survivorship curves. Failure rates were calculated without considering the variable of time, while survivorship curves take time into account.

Table 1 Failure modes related to gender and diagnosis

Failure mode	Study group (*N*=39/1216; 3.2%)			
	Men (*n*=20/867; 2.3%)		Women (*n*=19/349; 5.4%)	
	OA (*n*=829)	Dysplasia (*n*=38)	OA (*n*=253)	Dysplasia (*n*=96)
Femoral neck fracture	4 (0.5%)	1 (2.6%)	4 (1.6%)	1 (1%)
Femoral loosening	8 (1%)	1 (2.6%)	1 (0.4%)	0
Acetabular loosening	2 (0.2%)	1 (2.6%)	5 (2%)	4 (4.2%)
Deep infection	2 (0.2%)	0	0	0
Wear related failure	0	0	1 (0.4%)	2 (2.1%)
Psoas tendonitis	1 (0.1%)	0	0	0
Traumatic intertrochanteric fracture revised	0	0	1 (0.4%)	0
Total	17*	3**	12*	7**
	(17/829; 2.1%)	(3/38; 7.9%)	(12/253; 4.7%)	(7/96; 7.3%)

OA osteoarthritis

* *P*=0.03 between the failure rates in men and women with OA

** *P*=0.91 between the failure rates in men and women with dysplasia

Paired *t* tests were used to compare the numerical outcomes between pre-operative and post-operative visits; standard *t* tests were used to compare the differences in the numerical outcomes among different groups [15]. Chi-square tests were calculated when comparing categorical outcomes. Chi-square tests were also used to compare the differences of failure rates between groups without considering the time variable. Kaplan-Meier curves were plotted to evaluate the survivorship rates using revision as the end point. Cox proportional hazard regression models were used to evaluate the significance of each variable using both univariate and multivariate analyses. For all tests in this study, $\alpha=0.05$ was used as the level of significance. OrthoTrack (Midlands Orthopaedics, p. a., Columbia, SC) and JMP (SAS, Cary, NC, USA) were used for the statistical analyses in this study.

Results

In total, 1092 (1092/1216; 89.8%) cases completed their latest follow-up with latest X-rays available in 759

Table 2 Complication and failure modes among three different hip resurfacing arthroplasty (HRA) prostheses groups

Characteristics	Hybrid Corin	Hybrid Biomet	Uncemented Biomet
Case (*N*=1,216)	280	668	268
Average follow-up period (years)	7.5±0.8	4.8±0.8	3.2±0.4
Post-operative complications			
Dislocation	0	4	1
Sciatic nerve palsy	2	0	0
Traumatic intertrochanteric fracture repaired	1	0	0
Deep vein thrombosis (DVT)	1	0	0
Deep infection	0	2	0
Radiological findings[a]			
Reactive femoral shadow	4	6	1
Focal femoral neck narrowing	4	9	6
Femoral stem radiolucency	3	0	0
Partial acetabular radiolucency	0	3	1
Failures			
Femoral neck fracture	3 (1.1%)	5 (0.7%)	2 (0.7%)
Femoral loosening	7 (2.5%)	1 (0.1%)	2 (0.7%)
Acetabular loosening	3 (1.1%)	7 (1%)	2 (0.7%)
Deep infection	1 (0.4%)	1 (0.1%)	0
Wear related failure	2 (0.7%)	1 (0.1%)	0
Psoas tendonitiis	0	1 (0.1%)	0
Traumatic intertrochanteric fracture revised	0	0	1 (0.4%)
Total failure rate	16 (5.7%)	16 (2.4%)	7 (2.6%)

[a] 759/1216 cases had their X-rays available at the time of this study

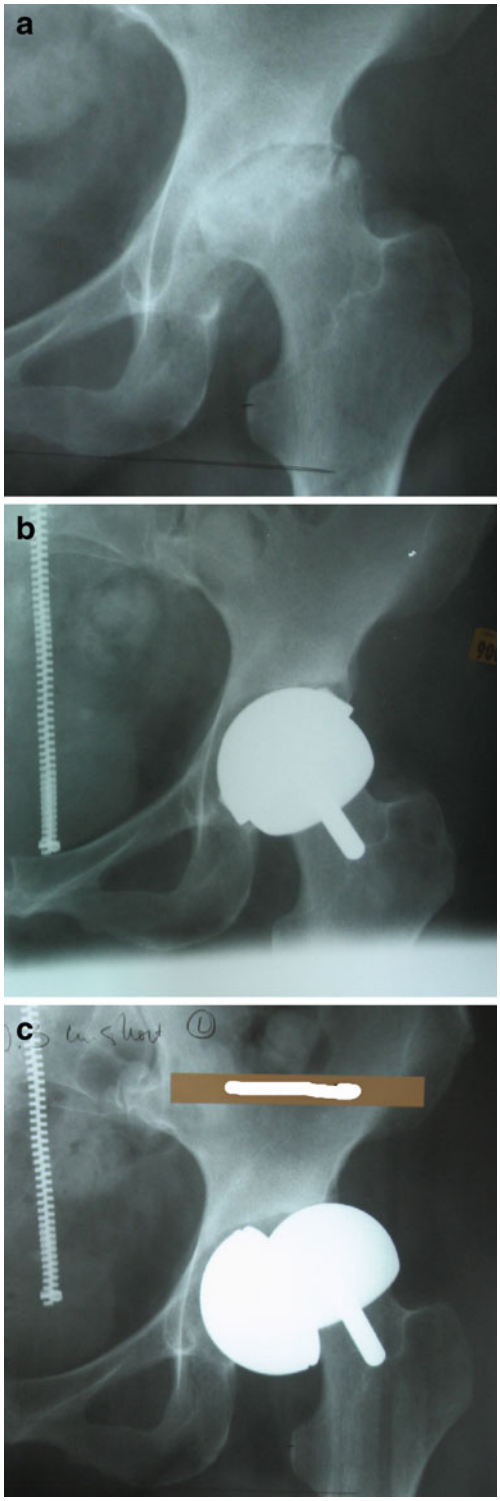

Fig. 1 X-ray of female dysplasia patients before metal-on-metal hip resurfacing arthroplasty (**a**), after hip resurfacing arthroplasty (**b**), and failure of acetabular fixation (**c**)

(62.4%) cases. The average length of follow-up was 5± 2 years (range 3–9 years). Eleven patients died due to causes unrelated to their hip surgery. Failures occurred in 39 of 1,216 cases (3.2%). Failure rates analysed by gender and diagnosis were listed in Table 1. Complications and failures were also tabulated individually for the three different prostheses (Table 2). Ten cases (0.8%) were revised due to femoral neck fracture and all occurred within six months post-operatively; 12 (0.9%) were revised due to acetabular component loosening (Fig. 1), ten (0.8%) were revised due to femoral component loosening, two (0.2%) were revised for deep infection, one (0.1%) traumatic intertrochanteric fracture was revised for psoas tendonitis, and three cases (0.3%) in two women were revised for adverse wear related failure. The three cases that were revised for adverse wear were all in women with acetabular inclination angles of greater than 60 degrees on standing anteroposterior pelvis X-rays who presented with pain, swelling, elevated metal ion levels, three dimensional imaging studies that showed fluid accumulation and metallosis at the time of surgery.

The overall failure rate for dysplasia cases was 10/134 (7.4%). Fifty percent of these were due to a failure of acetabular fixation, and 20% were due to acetabular component malposition resulting in an adverse wear reaction. Therefore, 70% of our failures in dysplasia were due to problems with the acetabular component. Overall, there was a 0.4% (5/1216) rate of dislocation, there were no revisions required for instability, and only one dislocation occurred in 134 dysplasia patients (0.7%).

At eight year follow-up post-operatively, women with the primary diagnosis of dysplasia had a survivorship rate of only 75% (Table 3). The survivorship rate was worse when dysplasia was compared to OA, when women were compared to men, but not when components<48 mm were compared to components≥48 mm, at nine year follow-up post-operatively (Fig. 2).

Based on Cox proportional hazard models, the primary diagnosis, the component size (grouped by 48 mm), and the gender all had a significant effect on the survivorship rate (Table 4). However, only the primary diagnosis showed a significant effect in the multivariate model with a *P*-value of 0.05 and a hazard ratio of 2.31. Size of femoral components had a much stronger, though not statistically significant, effect on the survivorship rate than gender in the multivariate model.

Other complications included dislocation in four cases, deep vein thrombosis (DVT) in one case, sciatic nerve palsy in two cases, and deep infection in two cases as well as one traumatic intertrochanteric fracture repaired at two years after the index procedure. Excluding the revised cases, the average post-operative HHS score for the whole group improved significantly from a preoperative score of 54±13 to 95±9 at the latest follow-up ($P<0.001$). The average postoperative UCLA activity score was 7±2, and the average visual analog scale (VAS) pain scale score was 0±1 on regular days and 2±2 on the worst days.

Table 3 Statistical significance of survivorship curves

Group	Survivorship rate				*P*-value 1	*P*-value 2
	2 years	5 years	7 years	9 years		
Total	98%	97%	97%	93%	—	—
Female	97%	96%	96%	89%	0.02	0.01
Male	99%	98%	97%	95%		
Dysplasia	95%	92%	86%	80%	0.006	0.001
OA	98%	98%	97%	95%		
< 48 mm	95%	94%	94%	94%	≤0.001	0.008
≥48 mm	99%	98%	97%	93%		
Female, dysplasia[a]	95%	95%	83%	71%	0.96	0.87
Male, dysplasia[b]	95%	90%	90%	90%		
Female, OA[a]	97%	96%	96%	94%	0.05	0.07
Male, OA[b]	99%	98%	97%	95%		
Female,<48 mm[c]	95%	94%	94%	94%	0.45	0.44
Male,<48 mm[d]	100%	100%	100%	100%		
Female, ≥48 mm[c]	99%	99%	95%	86%	0.78	0.42
Male,≥48 mm[d]	98%	98%	97%	95%		

OA osteoarthritis

P-value 1 tested the survivor functions; *P*-value 2 tested revision rates

[a] *P*-value 1 between the female groups with either OA or dysplasia=0.37; *P*-value 2=0.20

[b] *P*-value 1 between the male groups with either OA or dysplasia=0.02; *P*-value 2=0.01

[c] *P*-value 1 between the female groups with the femoral component size of either <48 mm or≥48 mm=0.03; *P*-value 2=0.23

[d] *P*-value 1 between the male groups with the femoral component size of either <48 mm or ≥48 mm=0.68; *P*-value 2=0.65

Radiological analysis of the nonrevised hips revealed three cases of femoral stem radiolucency. There were also 11 cases with a reactive femoral shadow, 19 cases of focal femoral neck narrowing presumed to be due to posterior-lateral impingement. There were four cases with partial radiolucency around the acetabulum. There were 20 cases with Brooker I [16], five cases with Brooker II, and one case with Brooker III heterotopic bone.

Discussion

Our data indicate that the higher prevalence of dysplasia in young women is the primary reason that women have a higher risk of failure after HRA. Although others have indicated that small component size and female gender are important negative risk factors for HRA, our results indicate that the high incidence of dysplasia in young women presenting for HRA is the main reason that women fare worse. Furthermore, 70% of our failures in dysplasia are related to acetabular component fixation or positioning. In contrast to a widely reported study by a UK group [17], failure due to adverse wear (pseudotumuor) has been seen in only three cases in women in our study (3/1216, 0.2%).

Dysplasia is more common in young women presenting for HRA. In our study group 89% of cases were due to OA and only 11% of cases were due to dysplasia. Only 4% of men had dysplasia, compared to 28% of women. Although men outnumbered women by more than 2:1 in this series, 72% of dysplasia cases were in women.

Although the results of HRA for dysplasia patients is worse than for OA, the same can be said for stemmed THA where the rate of dislocation rate in dysplasia cases is reported from zero to 11% [18] and the failure rate is also significantly higher than for OA [19–21].

Smaller femoral component size has previously been implicated as the risk factor accounting for the higher failure rate seen among women undergoing HRA [7, 22, 23]. None of these studies have included diagnosis in their multivariable analysis. Our data is in agreement with these studies—we find that small component size is a more important risk factor than female gender; however, when the additional variable of diagnosis (OA or dysplasia) was added into the multivariable analysis model, femoral component size became an insignificant risk factor (P= 0.09). Component size was found to be significantly smaller in dysplasia than in OA (P<0.001).

Others have reported that the outcomes for HRA are worse for dysplasia than for OA patients [24, 25]. In Amstutz's early study of dysplasia [18], there were more problems on the femoral side with a femoral neck fracture rate of 8.5%. Also, he noted that it was difficult to restore

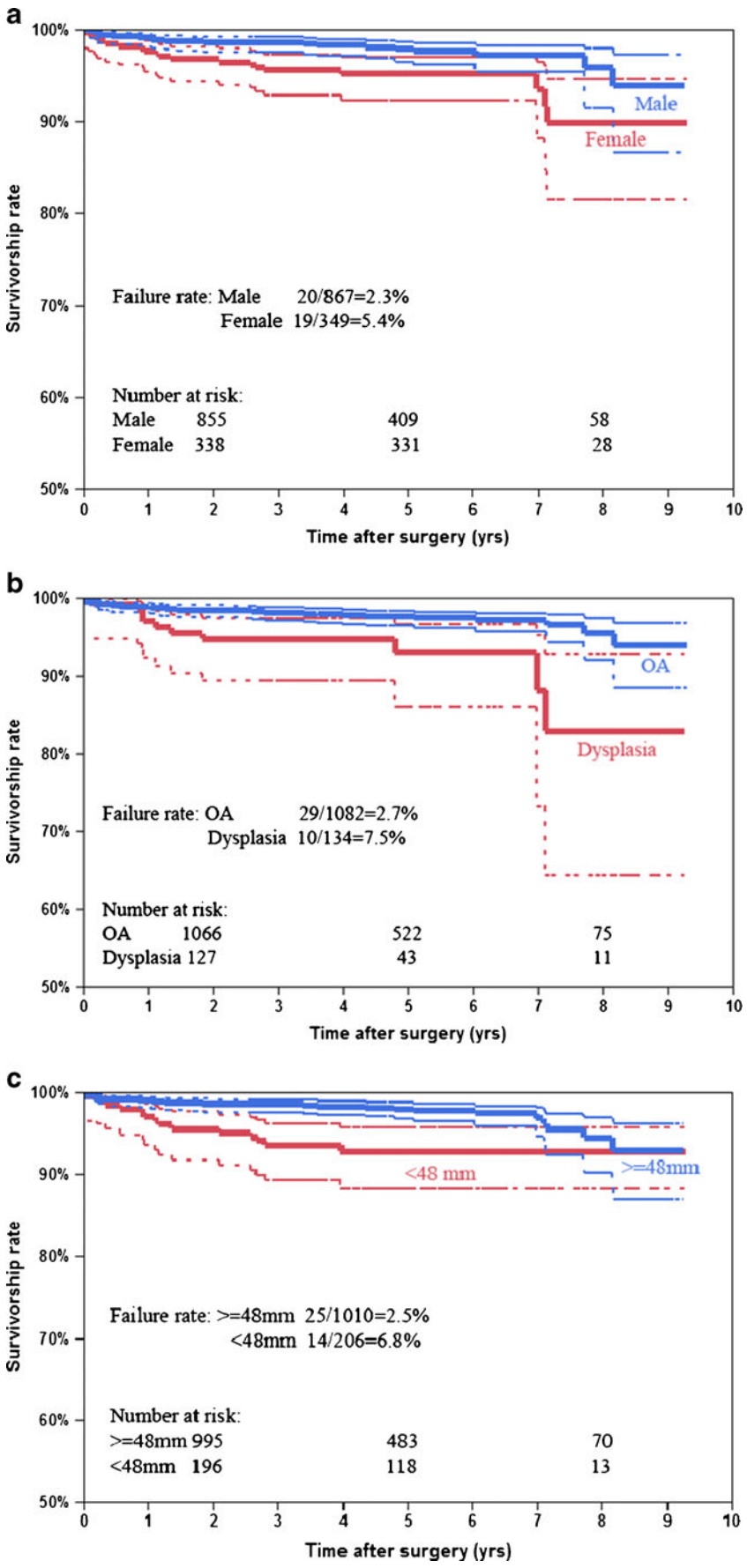

Fig. 2 Time-weighted Kaplan-Meier survivorship curves for the study group up to nine years post-operatively and time independent failure rates. **a** Revision for any reason taken as the end point for the female group and the male group. **b** Revision for any reason taken as the end point for the group with dysplasia and the group with osteoarthritis (OA). **c** Revision for any reason taken as the end point for the group with the femoral component size< 48 mm and with the femoral component size≥48 mm

Table 4 Results of univariate analyses and multivariate analysis with use of Cox proportional hazard regression models

Variables	*P*-value	Hazard ratio	95% Confidence interval	
Univariate analysis				
Age	0.94	1	0.96	1.04
BMI (<29/≥29)	0.56	1.22	0.64	2.45
Gender (female/male)	0.008*	2.37	1.25	4.45
Femoral fixation method (Cemented/Uncemented)	0.67	1.21	0.48	2.7
Size of femoral components (<48/≥48)	0.003*	2.93	1.48	5.56
Primary diagnosis (dysplasia/ osteoarthritis)	0.007*	2.96	1.37	5.87
Multivariate analysis				
Age	0.91	1	0.96	1.05
BMI (<29/≥29)	0.95	1	0.53	2.08
Gender (female/male)	0.76	1.26	0.43	2.85
Femoral fixation method (cemented/uncemented)	0.91	1.05	0.46	2.72
Size of femoral components (<48/≥48)	0.09	2.24	0.9	5.94
Primary diagnosis (dysplasia/osteoarthritis)	0.05*	2.31	1	5

BMI body mass index

* Statistically significant

equality of leg length with HRA. Our study confirms the findings in McBryde's case-control study [25] that acetabular problems are more common in dysplasia.

It is well known that dysplastic sockets are shallow and are often described as anteverted. We have noticed that they are always oval. This has been described in the literature, but is rarely emphasised. In our experience, the long axis of this oval is always from posterior/inferior to anterior/superior. We believe that this fact is responsible for the appearance of a more "anteverted" socket. It is also the reason that after reaming the socket, a wall deficiency sometimes remains in the anterior/superior quadrant of the socket. When the acetabular component is placed in the correct orientation, a variable degree of component "uncoverage" occurs that is difficult to quantify on postoperative plane X-ray (two dimensional). However, if the surgeon visually aligns the component with this deficient anterior superior corner, less coverage deficiency results; but instead the component may then be too anteverted and too steeply inclined. A dilemma exists—either place the component more anteverted and inclined and obtain good coverage of the porous coated wall (worse for wear, better for fixation), or place the component more horizontal and less anteverted and have a greater portion of the cup uncovered (better for wear, worse for fixation). The solution would seem to be using components with supplemental fixation placed in lower inclination and less anteversion, while grafting the defect that results. Mid-term studies have shown that the BHR using dysplasia components (with flanges and bolts), had fewer acetabular loosenings [26].

McMinn et al. have suggested [11] that another reason for higher wear-related failure in dysplasia might be due to excessive femoral component anteversion in dysplasia. This can only be measured using CT scans. We only had three adverse wear related failures (0.2%) that were related to acetabular malposition and performed no CT component measurements. We are therefore unable to evaluate whether femoral component anteversion played a role in our wear failures. In a CT based study, Hart has shown that while acetabular component inclination is strongly correlated with adverse wear, combined anteversion is only weakly correlated [27].

A limitation of this study is that a single experienced surgeon operated on all the cases in this study. Previous studies have shown that there is an extended learning curve for HRA [1, 28]. Therefore, the complications that are reported by a large single surgeon series may not reflect the same complications seen in national registries, which include HRAs performed by both experienced and inexperienced surgeons. We only evaluated the effect of gender, component size and diagnosis on the failure rate in HRA. Other factors may also be found to be significant upon closer analysis.

In summary, we have demonstrated that the higher prevalence of dysplasia in young women is the primary reason why women and patients with small component sizes have been found to have a higher failure rate with HRA. While others have had more problems with adverse wear in this patient population, we have had more problems with acetabular component fixation. Both of these problems are related to acetabular component implantation. Dysplastic patients also have a higher failure rate with stemmed THA. No direct comparison study exists. Therefore, we question the common recommendation to avoid HRA in young women. We suggest that it may be more productive to concentrate on developing more accurate implantation techniques (to avoid wear) together with the use of supplemental acetabular fixation such as flanges or spikes

(to avoid fixation failure) in cases with significant defects. This may allow dysplasia patients, who are at a high risk for dislocation due to their inherent tissue laxity, to benefit from the enhanced stability of large metal bearings.

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