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ORIGINAL PAPER

Debridement, antibiotics and implant retention for prosthetic joint infection: comparison of outcomes between total hip arthroplasty and hip resurfacing

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Abstract

Introduction The management of prosthetic joint infection (PJI) has been widely studied in the context of total hip arthroplasty (THA). However, the outcomes of debridement, antibiotics and implant retention (DAIR) for PJI have never been compared between hip resurfacing arthroplasty (HRA) and THA. This led us to carry out a retrospective case–control study comparing the surgical treatment of post-operative infections between HRA and THA to determine the infection remission rate and the medium-term functional outcomes.

Methods This single-centre case–control study analysed 3056 HRA cases of which 13 patients had a PJI treated by DAIR. These patients were age-matched with 15 infected THA hips treated by DAIR and modular component exchange (controls). Their survival (no recurrence of the infection) was compared and factors that could affect the success of the DAIR were explored: sex, body mass index, age at surgery, presence of haematoma, type of bacteria present and antibiotic therapy.

Results At a mean follow-up of five years (2–7), the infection control rate was significantly higher in the HRA group (100% [13/13]) than in the THA group (67% [10/15]) ($p = 0.044$). More patients in the THA group had undergone early DAIR (< 30 days) (73% [11/15]) than in the HRA group (54% [7/13]). There was no significant difference between the two groups in the ASA score, presence of comorbidities, body mass index and duration of the initial arthroplasty procedure. At the review, the Oxford-12 score of 17/60 (12–28) was better in the HRA group than the score of 25/60 (12–40) in the THA group ($p = 0.004$).

Conclusion DAIR, no matter the time frame, is a viable therapeutic option for infection control after HRA.

Keywords Total hip arthroplasty · Hip resurfacing · Prosthetic joint infection

Introduction

Hip resurfacing arthroplasty (HRA) is an alternative to total hip arthroplasty (THA) in young, active patients [1–4]. Whilst these two types of arthroplasties are subject to different types of complications, infection is a concern for both [5, 6]. The incidence of prosthetic joint infection (PJI) for primary THA (0.2 to 1.1%) [7–12] is within the same range of that reported with HRA (0.6%) [13]. Whilst the infection rate is low, this is a serious complication that causes morbidity and mortality and leads to higher costs for the healthcare system [14, 15]. Also, the quality of life of patients who suffer an infection after THA is often poor due to chronic pain, limited activities of daily living and need for human or technical assistance, independent of age and sex [16]. The management of PJI after THA is relatively well standardised

Level of evidence: Level III, case-control study.

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[17–20]. However, there is much less information on how to deal with HRA infection [21].

To our best knowledge, no study up to now has compared the outcomes of debridement, antibiotics and implant retention (DAIR) between HRA and THA. This led us to carry out a retrospective case–control study comparing the treatment of PJI by DAIR between HRA and THA to determine if there was a difference in the infection control rate and functional scores after the infection had been cured.

Methods

Study design

Out of 3036 HRA procedures over the eight year inclusion period (2010–2018), patients who suffered a PJI after HRA (case group) at our facility were identified retrospectively using the French National HRA registry [22]. At a mean follow-up of five years (2–7), 13 infections were identified in this cohort (0.4% infection rate) and treated by DAIR without modular component exchange.

During the inclusion period, 7607 THA procedures were done, and 139 infections were treated (of which 65 came from our facility, thus a 0.9% THA infection rate). The 13 patients who had undergone HRA were matched based on age with 15 patients who had undergone THA (control group) treated by DAIR.

Excluded were patients who had been operated upon at another facility; patients who had a history of a tumour in the operated hip, history of infection in the native hip at the time of replacement, fracture of the operated hip, immunosuppression or kidney failure and/or previous hip surgery; or patients who were more than 75 years old (Fig. 1).

The mean age was 53 years (47–58) in the HRA group and 59 years (45–66) in the THA group ($p = 0.34$). There was a predominance of male patients in the HRA group relative to the THA group (12 men vs. 3, $p < 0.001$). There was no significant difference between the two groups in the ASA score [23], presence of comorbidities, body mass index (BMI) [24] and the duration of the initial arthroplasty procedure. A post-operative haematoma developed in 60% of THA patients (9/15) versus 46% (6/10) of HRA patients ($p = 0.46$) (Table 1).

A posterolateral approach had been used during the initial procedure in both groups. All patients in the HRA group had received implants with a metal-on-metal (MM) bearing (BHR™ Smith & Nephew, Watford, England [1852 cases], or Conserve + ™ Wright Medical, Memphis, TN, USA [1184 cases]). The femoral component was secured with gentamycin-loaded cement (Palacos, Heraeus, Paris, France), whilst the acetabular component was fixed

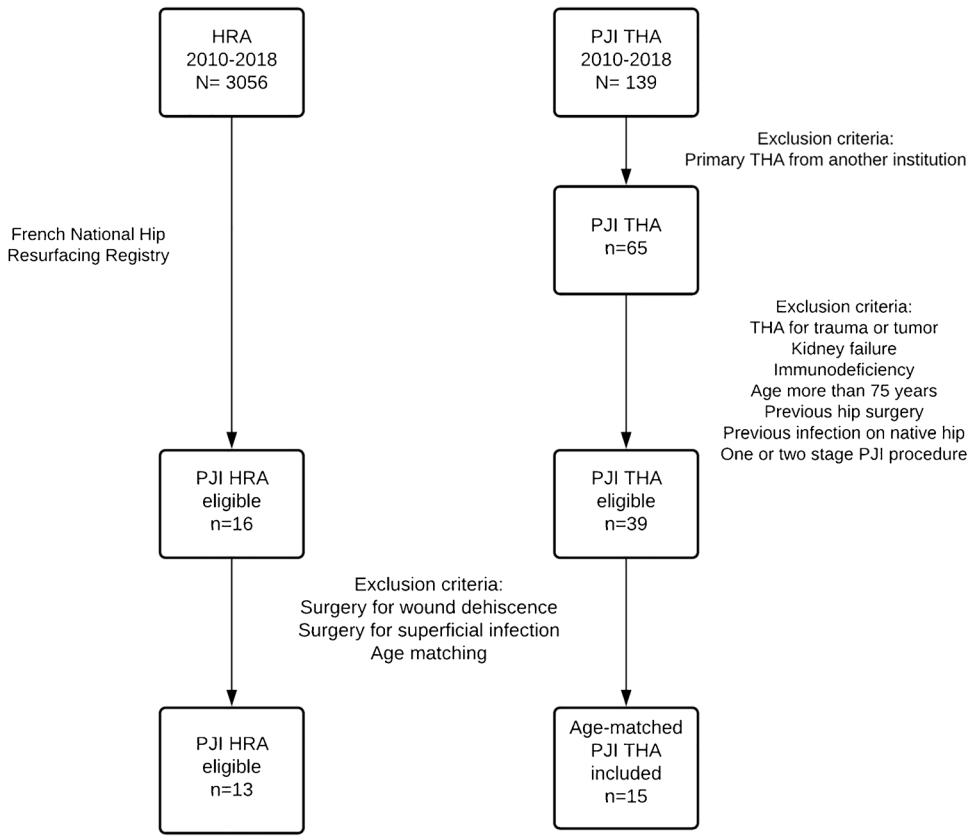


Fig. 1 Flowchart summarising the study design

Table 1 Characteristics of the patients in the PJI HRA and THA groups

Name			HRA ($N=13$)	THA ($N=15$)	p value
Age (years)	Mean (min; max)		53 (47–58)	59 (45–66)	0.34
Sex	*N* (%)	Male	12 (92%)	3 (25%)	< 0.001
		Female	1 (8%)	12 (75%)	
BMI [23] kg/m^2	Mean and SD		29.3 ± 4.1	32.7 ± 9.1	0.21
Smoker	*N* (%)		3 (23.1%)	1 (6.7%)	NA
Diabetes	*N* (%)		1 (7.7%)	4 (26.7%)	NA
ASA score[22]	*N* (%)	1	7 (53.8%)	5 (33.3%)	0.2
		2	5 (38.5%)	8 (53.3%)	
		3	1 (7.7%)	2 (13.3%)	
Primary diagnosis	*N* (%)	Primary hip OA	12 (92.3%)	12 (80.0%)	NA
		Slipped capital femoral epiphysis	0	1 (6.7%)	
		Osteonecrosis	1 (7.7%)	2 (13.3%)	
Duration of first implantation surgery (min)	Mean (min; max)		63 (51.0; 80.0)	71 (69.0; 90.0)	0.34
Postoperative haematoma	*N* (%)		6 (46.2%)	9 (60.0%)	0.46
Time to infection diagnosis	*N* (%)	≤ 30 days	7 (53.8%)	11 (73.3%)	0.43
		> 30 days	6 (46.2%)	4 (26.7%)	
Major MSIS criteria[24]	*N* (%)	≥ 1	11 (84.6%)	14 (93.3%)	
Duration of saline lavage (min)	Mean (min; max)		47 (42–52)	37 (30–42)	0.4
Length of hospital stay	*N* (days)		9 (7–10)	10 (12–22)	0.7
Metal ions in the whole blood at follow-up	Cobalt (MG/L), mean (min; max)	Missing data: 1	1.15 [0.6; 2.14]		
	Chrome (MG/L), mean (min; max)	Missing data: 1	0.97 [0.5; 1.52]		

PJI periprosthetic joint infection, *HRA* hip resurfacing arthroplasty, *THA* total hip arthroplasty, *SD* standard deviation, *NA* not applicable, *N* number, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *MSIS* Musculoskeletal Infection Society

cementless with hydroxyapatite coating (hybrid fixation). In the THA group, 6/15 (40%) had a ceramic-on-ceramic bearing (CC), 5/15 (27%) had a ceramic-on-polyethylene (PE-C) bearing, 3/15 (20%) had a MM bearing, and 2/15 (13%) had a metal-on polyethylene (PE-M) bearing (Table 2). All the implants in the THA group were cementless.

Treatment

The PJI was defined by the presence of one major MusculoSkeletal Infection Society (MSIS) criterion or four minor MSIS criteria [25]. The "time to infection" was defined as the time elapsed between the arthroplasty procedure and the clinical start of the infection. It was classified as early (≤ 1 month after implantation), delayed (> 1 and < 24 months after implantation) or late (≥ 24 months after implantation).

All patients underwent surgical revision within 24 h of the diagnosis of PJI. The revision consisted of debridement through the same surgical approach as the one used initially with extended synovectomy and abundant irrigation (6 L of saline using pulsed syringe). To preserve the MM bearing, no surgical dislocation was done in the HRA group. Hip dislocation with exchange of the

Table 2 Implant characteristics for the HRA and THA groups

			HRA ($n=13$)	THA ($n=15$)	$p$value
Bearing type	*N* (%)	MM	13 (100%)	3 (20%)	NA
		CC	0	6 (40%)	
		PE-C	0	4 (26.7%)	
		PE-M	0	2 (13.3%)	
Femoral head diameter	Median (min–max)		54 (52–56)	32 (28–36)	NA
Cup diameter	Median (min–max)		60 (58–62)	52 (52–54)	0.03

HRA hip resurfacing arthroplasty, *THA* total hip arthroplasty, *MM* metal/metal, *C/C* ceramic/ceramic, *PE/C* polyethylene/ceramic, *PE/M* polyethylene/metal, *NA* not applicable

modular components (femoral head, liner) was done in the THA group. Multiple samples were collected for microbiology in all patients (joint fluid, soft tissues, bone). Once the samples had been harvested, the patients received curative empirical antibiotic therapy involving a combination of cefepime (Axepim™) (2 g/8 h/day) + daptomycin (Cubicin™) (10 mg/kg/day) or ceftobiprole (Mabelio™) (500 mg–1 g/8 h) by the intravenous route until the mecA gene could be screened within 2 to 24 h of DAIR [26]. If the mecA gene was present (indicative of methicillin resistance), empirical antibiotic therapy was continued until results of the cultures and antibiotic sensitivity testing were available. If the mecA gene was not present, only cefepime IV was continued until the culture results were available. All the patients received appropriate oral antibiotics for 3 months after a multidisciplinary meeting in a national designated PJI centre upon receipt of these results [27]. The patients were seen at regular intervals at day 15, month, three months, six months, one year and then once per year.

Follow-up and outcome measures

No patients were lost to follow-up. The clinical review was done by a surgeon who was not involved in the surgical procedures.

Successful treatment equated to apparent control of the initial infection at a minimum follow-up of two years, defined by the MSIS criteria and the absence of clinical, radiological and laboratory signs of implant infection, ongoing antibiotic therapy and death attributed directly to the infection or the treatment [25].

A recurrence was defined as any open surgical procedure done to treat a persistent infection of the arthroplasty. This included revision of any major component (acetabular or femoral) along with exchange of the modular components (femoral head, liner), new DAIR and extended synovectomy to treat a PJI. The functional outcomes were evaluated using the Ofxord-12 [28].

Statistical analysis

The quantitative variables were described by the median value (interquartile interval and range). The normality of the distributions was verified graphically and using the Shapiro–Wilk test. Qualitative variables were described by their counts and percentages. Recurrence of the infection was compared between the cases (HRA) and controls (THA) using Fisher's exact test with a significance level of 5%. The statistical analysis was performed with SAS software (version 9.4, SAS Institute, Cary NC, USA).

Results

The infection control rate was significantly higher in the HRA group (100% [13/13]) than in the THA group (67% [10/15]) ($p = 0.044$) (Table 1). Two patients in the THA group died from reasons unrelated to the infection: one due to pancreas cancer and one due to a neuroendocrine tumour. These were discovered only after the inclusion date.

At the final review, the Oxford-12 score was better in the HRA group (17/60 (12-28)) than the THA group (25/60 (12-40)) ($p = 0.004$).

Early post-operative infections (< 30 days) occurred in 7/13 cases (54%) in the HRA group versus 11/15 cases (73%) in the THA group. A delayed infection (> 1 month and < 24 months) occurred in 4/13 HRA patients (31%) and in 5/15 THA patients (33%), whilst 1/15 HRA patients (7%) had a late infection (> 24 months) versus 0 in the THA group.

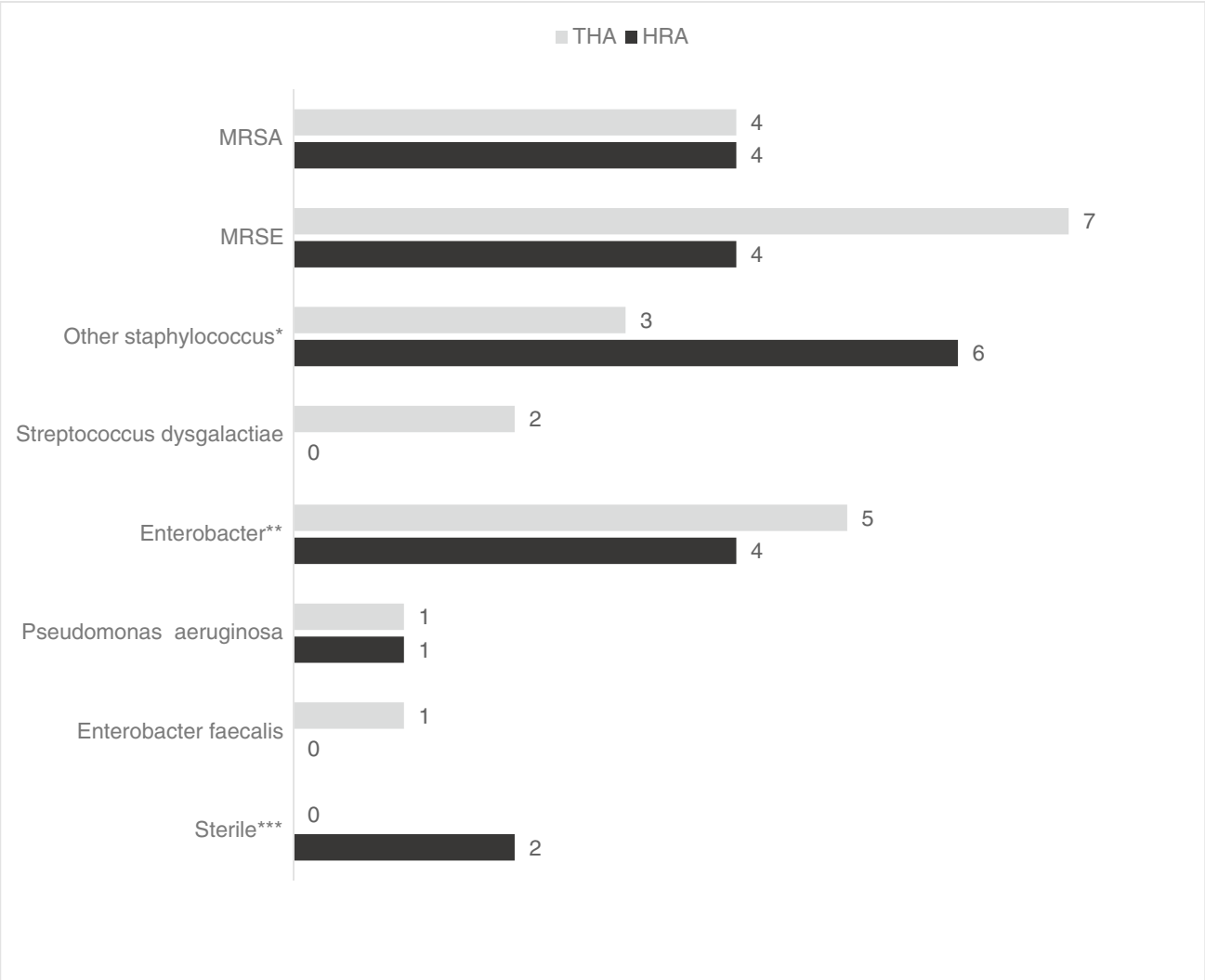
In the THA group, 11/15 patients (73%) had early DAIR (≤ 30 days) as did 7/13 patients in the HRA group (54%) ($p = 0.04$) (Table 1).

A single micro-organism was isolated in 14/28 patients (50%) whilst a polymicrobial infection was found in 12/28 cases (43%). The most commonly found bacteria were Gram-positive cocci in 24/28 patients (86%) (15 monomicrobial, 9 polymicrobial) followed by Gram-negative bacilli in 7/28 patients (28%). The samples came back as sterile in 2/28 patients (7%) (Fig. 2). These two patients had samples collected whilst they were receiving antibiotic therapy but had clinical evidence of an early postoperative infection (fistula, pus discharge). The type of infection (mono- or polymicrobial) had no significant effect on the success of infection control.

The length of hospital stay for PJI treatment was ten days (12–22) in the THA group and nine days (7–10) in the HRA group ($p = 0.7$). There was no difference between groups in the total duration of antibiotic therapy: 90 days (45–90) for the HRA group and 86 days (60–90) for the THA group ($p = 1.00$). The post-operative antibiotic relay consisted of rifampicin–levofloxacin in 9/15 THA patients (60%) and 6/13 HRA patients (46%). The blood ion concentration at follow-up did not show abnormal levels (Table 1).

Discussion

To our knowledge, this is the first study to compare the outcomes in two matched groups of HRA and THA patients after DAIR for a PJI. The results show better infection control in the HRA group (100%) than in the



* Others staphylococci:
- THA group: S. *hominis* (1); S. *lugdunensis* (1); *MRSA* (1)
- HRA group: S. *caprae* (2); S. *capitis* (2); S. *lugdunensis* (1); S. *hominis* (1); coagulase negative staphylococci (1)

** Enterobacter:
- THA group: *Escherichia coli* (2); *Proteus mirabilis* (3)
- HRA group: *Klebsiella oxytoca* (1); *Citrobacter freundii* (1); *Serratia marcescens* (1); *Morganella morganii* (1)

MRSA = Methicillin-resistant *Staphylococcus aureus*, MRSE= Methicillin-resistant *Staphylococcus epidermidis*,
HRA = Hip Resurfacing Arthroplasty, THA = Total Hip Arthroplasty

*** These two patients had their samples collected while receiving antibiotic therapy but had clinical evidence of an early postoperative infection (fistula, pus discharge)

Fig. 2 Compared microbiology of infected HRA and THA

THA group (67%). The main challenge with interpreting the results of other published studies on this topic is the variability in the criteria for defining a PJI and the variability in the medical care provided. The success rate of DAIR ranges from 26 to 88% (Table 3) [9, 29–33].

Cobo et al. [32] reported a 71% infection control rate in patients who underwent DAIR whilst Klouche et al.

Table 3 Results of main published studies on infection control after DAIR in THA

Author	Infection location	Year of publication	Number of patients	Mean FU (years)	Success rate (%)
Crockarell et al.[9]	Hip	1998	52	5	26
Marculescu et al. [3]	Hip and knee	2006	91	2	60
Cobo et al. [2]	Hip, knee, shoulder	2011	117	2.5	70
Klouche et al.[9]	Hip	2011	12	2	75
Bryan et al. [30]	Hip	2017	90	6	83
Current study	Hip	2021	28	5	67

FU follow-up, *DAIR* debridement, antibiotics and implant retention, *THA* total hip arthroplasty

[29] reported a 75% infection control rate in patients selected based on very narrow criteria. In the literature, failure of DAIR for infection control often corresponds to complex PJI in patients who have comorbidities [29–31]. The high rate of infection control after DAIR in our study can be explained by the fact that most of the patients were young and without comorbidities. The success rate of saline irrigation and single-stage implant change for infected THA is related to the one achieved in our HRA group [20, 31]. There are multiple reasons why the infection control rate was different between our HRA and THA groups. Since the femoral bone stock is preserved, HRA procedures do not place any devices inside the femoral medullary canal and do not expose the superior femoral metaphysis. Thus, the intra-osseous bacterial diffusion is extremely limited in HRA. The large implant volume (identical to the native diameter of the femoral head) induces a smaller amount of joint fluid than THA, which also reduces the space for bacterial diffusion. Therefore, the diffusion of curative antibiotic therapy is ideal and has broad access to the biofilm, which likely contributed to the different outcomes between the two groups [34–36]. The routine use of antibiotic-loaded cement is likely another important element.

The risk factors for failure of DAIR are relatively well-known: male sex, obesity, comorbidities, MM bearing, infection diagnosed more than 6 weeks after the primary arthroplasty [11, 17, 37–42]. In theory, the HRA group had many factors that could negatively affect the outcomes of DAIR:

- The delayed PJI rate was higher in the HRA group than the THA group.
- There were many more males in the HRA group (92%).
- A MM bearing had been used in every implantation. Debris from MOM bearings accelerated the growth of planktonic bacteria by providing a scaffold on which biofilm can grow. Moreover, the HRA group had no high concentration of chrome or cobalt, whilst level concentration above 200,000 µg/L seems to significantly reduce biofilm formation [43].

Nevertheless, there were no failures of DAIR in the HRA group, which validates this surgical option no matter when the infection is diagnosed. Whilst current data suggest that DAIR is best for early infections (≤ 30 days) and that implant revision (one or two stages) or repeated saline irrigation for chronic infections is best for patients who have undergone THA, our surgical strategy for HRA appears to be a valid option even for a delayed infection diagnosis [9, 18, 20, 41, 42].

The functional outcomes of the HRA group were excellent and better than in the THA group. Thus, DAIR does not appear to negatively affect the functional prognosis of patients who have undergone HRA. The Oxford-12 score was identical to those of primary HRA procedures free of complications [1–4]. The fact that the hip is not dislocated to protect the bearing may cause less soft tissue damage than after dislocation and modular component exchange in the THA group.

Our study has several limitations. (1) This was a retrospective study. Thus, any variability in the data collection is a potential bias. However, the data were taken from an exhaustive national registry, which limits the loss of information. (2) The inclusion period was long; patient care may have changed over the years. Nevertheless, all patients were treated according to the same protocol by experienced surgeons in a university hospital and designated PJI centre [27]. (3) There is a potential selection bias for the THA and HRA indications. However, the two cohorts were relatively similar in their risk factors for infection (BMI, ASA, etc.), which minimises the risk of heterogeneous results on factors related to the patient. (4) Even though we included all PJI of HRA, the small sample size in the HRA group did not allow us to carry out a multivariate analysis and to look for causal factors for infection recurrence. Because of the low infection rate after hip arthroplasty, it is difficult to compile enough patients who have this complication and

so interpretation and conclusion of our work should be taken cautiously.

Conclusion

At 0.4%, the PJI rate for HRA is low. DAIR, no matter the time frame, is a viable therapeutic option for infection control in patients who underwent HRA since there were no recurrences in our cohort. DAIR does not appear to negatively affect the functional outcomes of HRA. These good results for HRA can be explained by the preservation of bone stock, excellent access to the biofilm and use of antibiotic-loaded cement.

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Author contribution E. Castanet: collected and analysed the data.

P. Martinot: performed the operations, analysed the data, prepared and approved the manuscript.

J. Dartus: performed the operations, analysed the data, prepared and approved the manuscript.

E. Senneville: performed the antibiotics and infection management, prepared and approved the manuscript.

H. Migaud: performed the operations, prepared and approved the manuscript.

J. Girard: designed the study, performed the operations, prepared and approved the manuscript.

Declarations

Ethics approval This study was conducted in accordance with principles of the Declaration of Helsinki and did not require ethics committee approval in France since it was conducted in a retrospective manner after obtaining patient authorization for use of their data.

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

Competing interests Henri Migaud is an education and research consultant for Zimmer, Corin, SERF and MSD and chief editor for Orthopaedics & Traumatology: Surgery & Research (Elsevier). E. Senneville is paid consultant for Zimmer-Biomet. Julien Girard is an education and research consultant for MicroPort, Smith & Nephew and Zimmer-Biomet. All other authors declare no competing interests.

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