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■ HIP

Influence of head size and sex on the five-year survival of ceramic-on-ceramic hip resurfacing

AN INTERNATIONAL MULTICENTRE STUDY

Aims

Ceramic-on-ceramic hip resurfacing (CoCHR) has been introduced to mitigate the risk of adverse tissue reactions associated with metal-on-metal hip resurfacing (MoMHR), particularly in females and smaller component sizes. This study evaluated: the survival of the ReCerf hybrid CoCHR up to five years; the impact of sex and component size on revision; and improvement in functional outcomes as measured by the Oxford Hip Score (OHS) and the University of California, Los Angeles Activity Scale (UCLA).

Methods

An international retrospective study included 604 consecutive patients (336 males, 268 females; mean age 50.1 years (20 to 80)) who underwent CoCHR from September 2018 to January 2023. Kaplan-Meier analysis assessed up to five-year survival, with log-rank tests comparing outcomes by sex and femoral head size. Cox proportional hazards regression quantified revision risk.

Results

Mean follow-up was 4.04 years (1.44 to 6.35). Survival in 128 hips which had five-year follow-up was 98.0% (95% CI 96.3 to 99.0): 97.6% for males (95% CI 94.7 to 98.9), 98.5% for females (95% CI 96.0 to 99.4), 98.5% for femoral head sizes < 50 mm (95% CI 96.1 to 99.4), and 97.5% for head sizes ≥ 50 mm (95% CI 94.6 to 98.8). Females had a revision hazard ratio (HR) of 0.79 (95% CI 0.14 to 4.26; $p = 0.780$) and an increase in head diameter by 1 mm of 1.01 (95% CI 0.83 to 1.23; $p = 0.890$), demonstrating no significant impact of sex or head size on revision incidence. Significant improvements in OHS and UCLA scores were observed for all patients (preoperative OHS 22.3 (SD 8.4) and postoperative OHS 45.0 (SD 4.1); preoperative UCLA 4.96 (SD 2.2) and postoperative UCLA 7.97 (SD 1.7)).

Conclusion

CoCHR demonstrated excellent patient-reported outcome improvement and survival up to five years, irrespective of sex or implant size, comparing favourably to MoMHR. Longer-term follow-up is required to confirm these outcomes.

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Introduction

Hip resurfacing has been a compelling alternative to total hip arthroplasty (THA), particularly for younger, more active patients who wish to continue being active and preserve femoral bone stock for potential future revisions.^{1,2} Despite its appeal, metal-on-metal (MoM) articulation has raised significant concerns, primarily due to metal ion release issues and adverse reactions to metal debris (ARMD).^{3,4} The National Joint

Registry, which uses data from England, Wales, Northern Ireland, the Isle of Man, and the States of Guernsey, reported notably high failure rates in the DePuy Inc Articular Surface Replacement (USA) due to metallosis, ultimately leading to its withdrawal. These clinical concerns resulted in the withdrawal of several failing implants, a significant reduction in the use of MoM hip resurfacing (MoMHR), and a cessation of MoM articulations in THA.⁵

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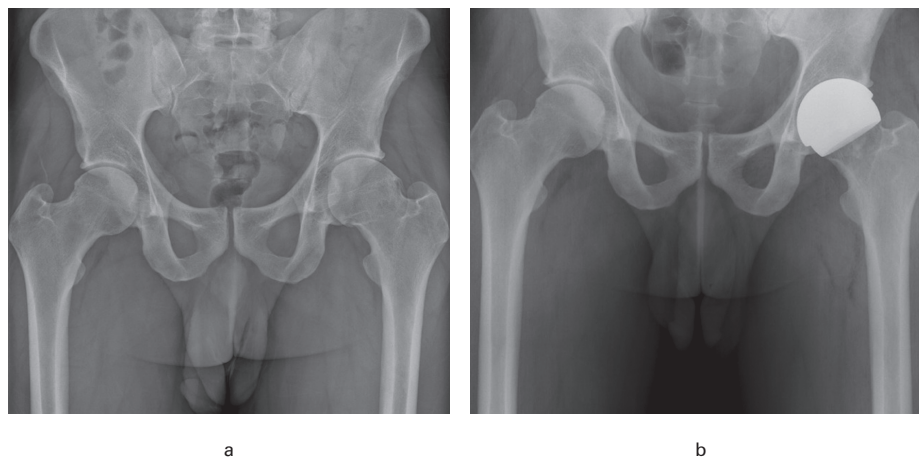


Fig. 1

Left: anteroposterior radiograph for an active 48-year-old male with symptomatic Tönnis 2 hip arthritis. After discussion, decision was made to undertake an anterior approach ceramic-on-ceramic hip resurfacing (CoCHR) with templated head size of 48 mm diameter. Right: six weeks postoperatively, the patient resumed near-normal sport activity.

Studies have suggested a higher revision risk for MoMHR in females. However, this may be influenced by other confounding factors such as smaller femoral head sizes, ligamentous laxity, higher prevalence of acetabular dysplasia, increased sensitivity to MoM implants, and variations in bone quality.^{3,5-9} In a 2013 article, the Canadian Arthroplasty Society warned against the use of hip resurfacing in females and smaller femoral components due to higher failure rates.¹⁰ However, MoMHR in appropriately selected patients has a 25-year survival rate of 83.5% (95% CI 0.79 to 0.9), underscoring the durability of MoMHR in younger, active individuals.^{2,11} Additionally, numerous studies have shown hip resurfacing produced improved walking speed with a more physiological and symmetrical gait pattern than THA.^{1,12,13} Although THA with highly cross-linked polyethylene (XLPE) has also demonstrated excellent survival in a small population, THA has a higher risk of dislocation over hip resurfacing, causes greater femoral bone loss, and can constitute a more complex concern when complicated by infection or periprosthetic fracture. In short, there is an unmet need for active female patients and patients with smaller femoral head sizes who suffer from arthritis but remain a high-risk group for MoMHR. To address this, ceramic-on-ceramic (CoC) hip resurfacing (CoCHR) has been introduced to reduce failures seen with MoMHR, especially in these patient groups.¹⁴⁻¹⁷

This study aimed to evaluate survival of CoCHR up to five years; influence of sex and component size on five-year survival; and two-year patient-reported outcome measures (PROMs), including the Oxford Hip Score (OHS)^{18,19} and the University of California, Los Angeles Activity Scale (UCLA),²⁰ following hybrid CoCHR.²¹

Methods

Study design. This retrospective case series involved 604 patients (604 hips) across five countries who underwent CoCHR with the MatOrtho ReCerf Ceramic HR System (UK) from September 2018 to January 2023. Of these patients,

336 were males, and 268 were females, with a mean age of 50.1 years (SD 9.241, 20 to 80) and a mean BMI of 27.7 kg/m² (SD 7.4, 18.2 to 42.6). Indications for CoCHR were osteoarthritis (593 patients), avascular necrosis (six patients) with Surface Arthroplasty Risk Index ≤ 2 , mild acetabular dysplasia (four patients), and post-traumatic arthritis (one patient). This study was registered with the ISRCTN registry (ISRCTN93110271) and obtained Institutional Research Ethics Board approval from Ottawa General Hospital.¹⁶

Patients. Inclusion criteria for CoCHR were determined based on patient expectations and the surgeon's clinical judgement. The surgical decision was made by the individual surgeon, considering the patient's activity level, bony anatomy, age, and the surgeon's experience. All patients meeting these criteria were included in the study. All participating surgeons were trained in hip resurfacing and had prior experience using the MatOrtho ADEPT HR System, which the ReCerf design was based on, with an Orthopaedic Data Evaluation Panel (ODEP) 15 A status.²²

Implant. The articulating surface is composed of highly polished (Ra < 0.02 μm) CeramTec BIOLOX delta Ceramic (Germany), with a cemented femoral component articulating against an uncemented acetabular component (Figure 1). The ReCerf acetabular component is a monobloc device featuring highly porous acetabular interfaces coated with DeltaFIX (titanium plasma spray and hydroxyapatite) and implanted using an optimal interference in-line technique. The ReCerf hip resurfacing device closely maintains the geometrical principles of the ADEPT HR, with a notable modification: a shorter femoral stem. Femoral head diameters are available in 2 mm increments, each paired with an acetabular component 6 mm larger. The articular arc remains consistent at 160° across all sizes, ensuring no smaller component reduction.

Data collection. All patients were prospectively recruited, and demographic data were collected. The surgical approaches used were the posterior capsular-preserving technique and the Hueter-anterior approach based on the operating surgeon's preference

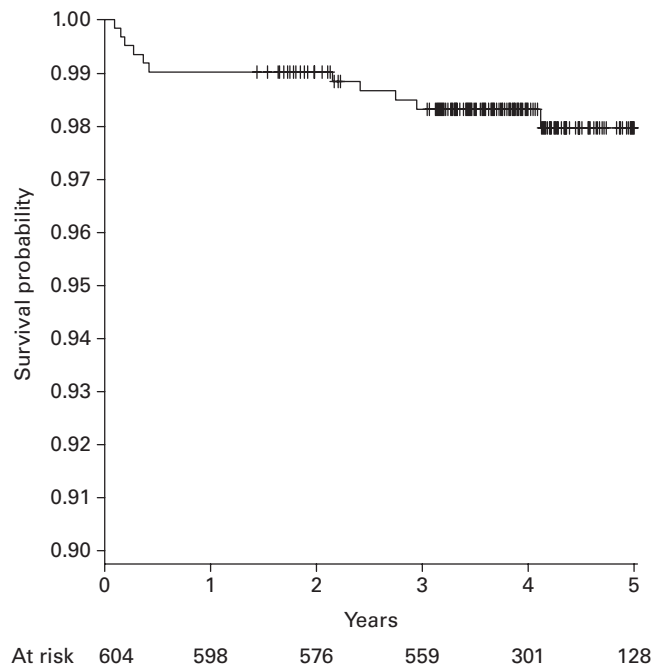


Fig. 2

Overall five-year Kaplan-Meier survival curve for patients who underwent ceramic-on-ceramic hip resurfacing, showing survival of 98% (95% CI 96.3 to 99.0).

and experience, as described in previous studies.^{16,23,24} Implant details were recorded in the operative notes for each patient.

Postoperative follow-ups were conducted at two weeks, six weeks, six months, and one year. Annual follow-ups were performed thereafter, with plain radiographs to assess for component migration or loosening. OHS and UCLA scores were collected at two years postoperatively. Patients were required to confirm whether they had undergone revision surgery at any other facility. Detailed indication, procedure, surgeon, and hospital information were collected in revision cases. The final follow-up date was set to 31 January 2025.

Endpoint. The primary endpoint was the occurrence of revision surgery, defined as any reoperation (with or without component exchange). Following guidance from the Medicines and Healthcare Products Regulatory Agency (MHRA), we further categorized the incidence of revision based on two high-risk groups, specifically females and patients with a femoral head size < 50 mm.²⁵ The secondary endpoint was the improvement in OHS and UCLA score, analyzed across all patients, with subgroup comparisons between male and female patients and different femoral head sizes.

Statistical analysis. Kaplan-Meier survival analysis was used to estimate five-year implant survival. The log-rank test assessed differences in survival between groups by sex and femoral head size. Cox proportional hazards regression models were applied to quantify the impact of sex and femoral head size on revision risk. Hazard ratios (HRs) with 95% CIs were reported. Changes in patient-reported outcomes (OHS and UCLA scores) were compared between groups using paired and independent-samples *t*-tests. All analyses were performed using

Table I. Distribution of head sizes and sex with raw percentage of revision (n = 604).

Risk factors	Number	Number revised	Raw percent revised*
Head diameter, mm			
40	2	0	0.00%
42	22	0	0.00%
44	66	1	1.52%
46	97	2	2.06%
48	96	1	1.04%
50	98	2	2.04%
52	90	3	3.33%
54	73	0	0.00%
56	37	0	0.00%
58	18	1	5.56%
60	4	0	0.00%
64	1	0	0.00%
Total	604	10	1.66%
Sex			
Male	336	6	1.79%
Female	268	4	1.49%
Total	604	10	1.66%

*Raw percentage is not time-dependent.

SAS v. 9.4 (SAS Institute, USA). Statistical significance was set at $p < 0.05$ for all tests.

Results

At a mean follow-up period of 4.04 years (1.44 to 6.35), survival up to five years was 98.0% (95% CI 96.3 to 99.0) (Figure 2). In total, ten revisions occurred (six males and four females) at a mean of 14.3 months postoperatively (1 to 34) (Table I). The mean age of patients undergoing revision was 48.6 years (38 to 67) with a mean BMI of 24.1 kg/m² (18.2 to 28.4). A total of 283 patients (46.9%) had a femoral component size < 50 mm (Table I). A total of 128 patients (21.2%) had a follow-up period exceeding five years postoperatively. No revisions were noted among these patients at the final follow-up date of 31 January 2025.

Survival up to five years and subgroup analysis. Survival up to five years was 97.6% for males (95% CI 94.7 to 98.9), 98.5% for females (95% CI 96.0 to 99.4), 98.5% for femoral head sizes < 50 mm (95% CI 96.1 to 99.4), and 97.5% for head sizes ≥ 50 mm (95% CI 94.6 to 98.8) (Figures 3 and 4). The HRs of revision for females compared to males was 0.78 (95% CI 0.14 to 4.26; $p = 0.780$). The HR for revision with increasing component size (by 1 mm) was 1.01 (95% CI 0.83 to 1.23; $p = 0.890$). Sex (female HR 0.79 (95% CI 0.15 to 4.3); $p = 0.780$) and component sizes (HR 1.01 (95% CI 0.83 to 1.2); $p = 0.890$) did not affect revision incidence.

Causes for revision. Two cases of cup loosening were documented: one due to technical factors and the other implant-related factors (Supplementary Table i). Revisions due to unexplained pain were observed in four cases despite investigations ruling out aseptic loosening, impingement, periprosthetic fracture, and infection. One case was attributed to a misdiagnosis of L5 nerve root impingement, although radiological findings indicated a slightly anteverted cup position. Three fractures were reported, with two resulting from an early transition to high-impact

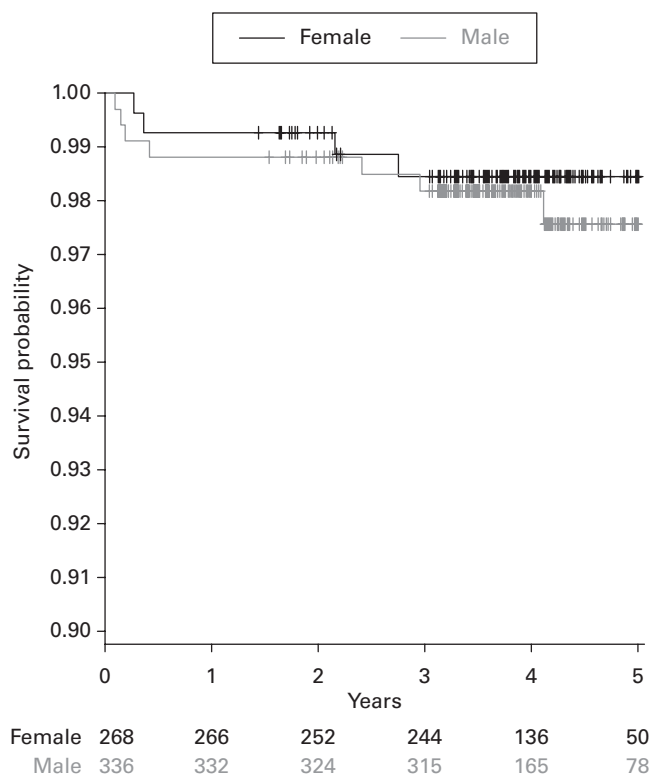


Fig. 3

Kaplan-Meier survival stratified by sex. Survival up to five years for females was 98.5% (95% CI 96.0 to 99.4) and males 97.6% (95% CI 94.7 to 98.9), with no significant difference noted between males and females ($p = 0.780$).

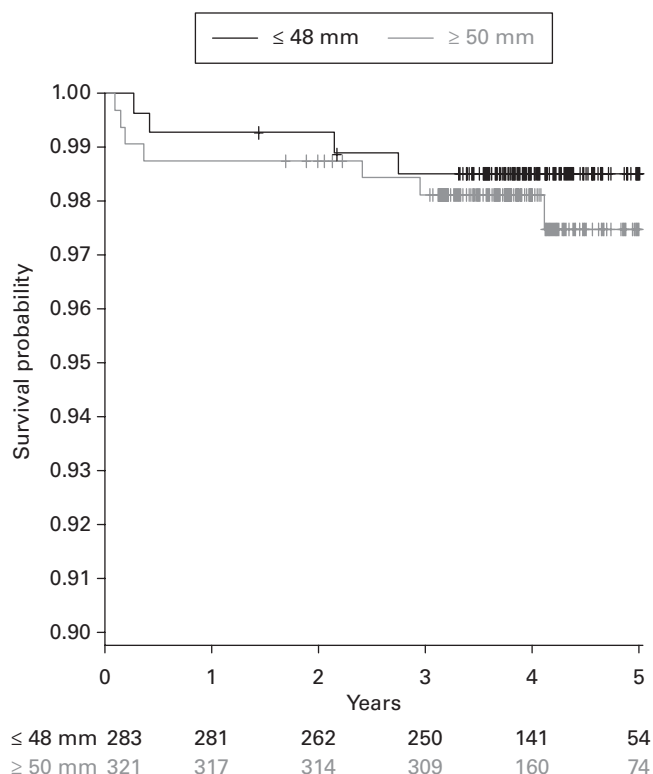


Fig. 4

Kaplan-Meier survival stratified by head sizes (< 50 mm and ≥ 50 mm). Survival up to five years for < 50 mm was 98.5% (95% CI 96.1 to 99.4) and ≥ 50 mm 97.5% (95% CI 94.6 to 98.8), with no significant difference noted with different head sizes ($p = 0.890$).

activities. No gross radiological notching was noted in the three patients with fractures; all three femoral head diameters were greater than 50 mm. One patient reported atraumatic insidious pain at two years postoperatively and underwent revision due to worsening pain. Intraoperatively, the surgeon observed that the hydroxyapatite coating could be easily detached from the ceramic cup's back-side surface using a curette. As such, the component underwent thorough investigation and finite element analysis, which could not determine any issue. All components over two years postoperatively were then closely monitored, and this phenomenon did not recur.¹⁶ In conclusion, all but one of the revisions were determined to be preventable and unrelated to the implant.

PROMs. Approximately 77% of patients completed preoperative and postoperative OHS for comparison at two years, and 70% for UCLA scores (Table II). Significant improvements in both OHS and UCLA scores were observed across the entire cohort. The improvement in UCLA scores was significantly greater in male patients ($p = 0.030$, independent-samples t -test). In contrast, no significant differences in OHS improvement were observed between males and females or across different head sizes (Table II).

Discussion

This study evaluated survival of a novel ceramic-on-ceramic hybrid resurfacing arthroplasty; evaluated whether smaller

head sizes or female sex were risk factors for revision, as they are established risk factors for failure of metal-on-metal resurfacing devices;^{3,5,7,26} and reported two-year changes in OHS and UCLA Activity Scale. In the total cohort of 604 patients, we found excellent survival regardless of head sizes and patient sex. There was a 98.0% survival in 128 patients with five-year follow-up, and improvements in PROMs consistent with previous THA and HRA studies.

Numerous studies have reported an association between females and smaller femoral heads with a higher revision rate for MoMHR. However, sex itself is not a direct cause of failure, as various confounding factors linked to females, such as those previously discussed, may contribute.^{8,17,26,27} This is especially relevant to MoMHR as the arc of cover would decrease with smaller components, increasing the risk of edge loading. Accurate placement of the acetabular component in both the coronal and axial planes is essential to prevent edge loading, which leads to abnormal wear patterns and elevated metal ions seen in MoM articulation.^{28,29} Looking further at other relevant risk factors, Amstutz and Le Duff,²⁶ in their single-surgeon cohort of 1,101 patients, used a multivariate model to analyze risk factors specific to sex and revealed a five-year survival for females of 100% with no risk factor, 92.1% with one risk factor, 95.8% with two risk factors, and 87.5% with three or more risk factors. The risk factors for females were contact patch ratio ≤ 7 mm,

Table II. Patient-reported outcome measures at two years postoperatively showing significant improvement postoperatively for all patients.

Group	Mean OHS (SD)		Improvement (95% CI)	Available for comparison, n	p-value*	Mean UCLA (SD)		Improvement (95% CI)	Available for comparison, n	p-value*
	Preop	Postop				Preop	Postop			
Male	22.4 (8.2)	45.3 (4.8)	22.6 (21.5 to 23.7)	281	0.550	4.95 (2.3)	8.14 (1.7)	3.2 (2.9 to 3.5)	262	0.030
Female	22.2 (8.6)	44.6 (5.3)	23.1 (21.7 to 24.5)	186		4.98 (4.9)	7.7 (1.9)	2.6 (2.3 to 3)	156	
≥ 50 mm	22.2 (8.1)	45.3 (3.8)	22.8 (21.7 to 24)	265	0.910	4.98 (2.3)	8.16 (1.6)	3.2 (2.9 to 3.5)	245	0.060
< 50 mm	22.1 (8.6)	44.6 (5.7)	22.7 (21.4 to 24)	203		4.93 (2.1)	7.69 (1.8)	2.7 (2.4 to 3.1)	173	

*Independent-samples *t*-test.

OHS, Oxford Hip Score; UCLA, University of California, Los Angeles activity scale.

Table III. Comparison of ceramic-on-ceramic hybrid resurfacing five-year revision risk with metal-on-metal hip resurfacings, based on sex and head sizes.

Author	Year	Location	Cohort, n	Five-year revision risk, sex		Five-year revision risk, head sizes	
				Female, %	Male, %	< 50 mm, %	≥ 50 mm, %
Canadian Arthroplasty Society	2013	Canada	2,773	6.4	2.6	6.2	2.4
Smith et al ⁵	2012	UK	31,932	8.3	4.1	8.3	2.6
Suraci et al ²⁴	2021	Canada	555	11.2	3.9		3.9
AOANJR	2021	Australia	13,300	10.6	5	15.3	4.5
NZJR	2021	New Zealand	2,982	9.8	5.2	13.9	3.8
Current study	2024	Multiple	604	1.5	2.4	1.5	2.5

AOANJR, Australian Orthopaedic Association National Joint Replacement Registry; NZJR, New Zealand Joint Registry.

aetiology of hip dysplasia, and first-generation femoral preparation technique. Although a head size of < 48 mm in the male group was deemed a significant risk factor, no subgroup analysis on the influence of head sizes in the female cohort was done. However, the surgeon's vast clinical experience in hip resurfacing must complement the relatively low revision rate.

MoMHR devices have been affected by issues related to ARMD and other complications (Table III). In a retrospective series of 555 MoMHR, Suraci et al²⁴ reported a five-year survival of 88.8% (95% CI 81.9 to 95.7) for the female cohort. Smith et al⁵ analyzed the National Joint Registry for England and Wales to determine the impact of sex and head sizes on revision incidence in a total cohort of 434,560 hip arthroplasties (31,932 hip resurfacing) using a multivariable flexible parametric survival model. They concluded that female sex is associated with a higher revision rate, regardless of head size compared to males at five years (46 mm female 6.1%, 44 mm female 7.1%, and 42 mm female 8.3%), implying other underlying risk factors associated with females, apart from head sizes. Their findings are not dissimilar to other joint registries, which reported gross survival of approximately 90% for females compared to 95% for males and approximately 85% for head size < 48 mm and 96% for head size ≥ 48 mm.^{30,31} More recently, the Canadian Arthroplasty Society released its review of 2,773 hip resurfacings, which have a five-year survival favouring males (97.4% vs 93.6%) and bigger head sizes (Table III). In our study, 128 hips had five-year follow-up, and the revision rate (2.0%) compares favourably to MoMHR; and to the revision rate of CoC THA, which has a revision rate of 2.5% to 2.9% at five years in numerous joint registries.^{5,30-32}

The MatOrtho ReCerf consists of a monoblock acetabular shelf which has been proven to increase initial fixation and promote osseointegration without affecting bone mineral density.³³ The ceramic bearing was made of BIOLOX delta (CeramTec), which has excellent biocompatibility and resistance to critical impact load.^{34,35} While pre-implantation testing

showed very reassuring bonding characteristics, there remains a theoretical risk of debonding between the plasma-sprayed coating and the ceramic inner shelf, leading to failure, which was only observed in one previously reported case.¹⁶ Like the predicate ADEPT MoMHR arthroplasty (MoMHRA), ReCerf utilizes a cemented femoral head philosophy. While cementing of the femoral component may raise concerns about implant deformation and bone thermonecrosis, historic clinical and registry outcomes with this concept have been reassuring. With specific regard to CoCHR, a biomechanical study by Farrier et al³⁶ comparing cementing for metal implant and ceramic (BIOLOX delta) revealed lower average temperature increment for ceramic implant, less deformation, and better dimensional stability for ceramic following cementing with Simplex cement (Stryker Orthopaedics, USA).

Only one study analyzed the viability of CoCHR and reported an unacceptable failure rate of a novel CoCHR device (ESKA, Germany) due to ceramic fracture causing third body and catastrophic metal wear.³⁷ The implant comprised a modular acetabular component and used a novel ceramic bearing (polyurethane and alumina). The strength, toughness, wear resistance, friction, and biocompatibility of the novel ceramic device with polyurethane and ceramic powder were unproven. In addition, its modular design further increases the risk of crevice corrosion. So far, we have not encountered any ceramic fracture in our five-year series. Alternatively, the use of metal on XLPE hip resurfacing has been reported in several studies with particularly good to excellent outcomes.^{14,15,38}

In this series, periprosthetic femoral neck fracture was the leading cause of failure, with an incidence of 0.6%. This complication is not related to the bearing surface and is a well-recognized risk following hip resurfacing, with a reported incidence of slightly less than 1%, according to the Canadian Arthroplasty Society.¹⁰ Despite being thought to be associated with surgical experience, we believe femoral neck fracture after hip resurfacing is multifactorial, as bone quality, blood supply,

implant placement, and the amount of cement penetration may affect fracture risk.³⁹ Secondly, patients should be cautioned against early return to high-impact activity postoperatively. Of all the revision cases, only one was noted secondary to implant-related failure. In short, careful patient selection and sensible postoperative rehabilitation can moderate many risk factors associated with this early complication.

Regarding postoperative patient outcomes, improvements were consistent with findings from known literature. A meta-analysis reported an average UCLA score of 7.28 following hip resurfacing.⁴⁰ Female patients were reported to have a postoperative UCLA score of 7.2, while male patients scored 8.2, consistent with our findings, which reflects higher activity levels following hip resurfacing compared to THA, with patients more frequently engaging in activities such as cycling, swimming, and golf.^{41–44}

This study is subject to the inherent limitations associated with retrospective analyses. Because of the multicentre international study structure, PROMs, pain levels, and detailed radiological evaluations are limited. Although only short-term outcome measures were available (two years), OHS and UCLA scores indicated significant improvement following the CoCHR, irrespective of sex and head size. We also acknowledge that using revision surgery as the primary endpoint may fail to account for current patients experiencing ongoing pain who remain under investigation or who are awaiting revision surgery. Additionally, while the maximum follow-up period was 6.35 years, the mean follow-up was 4.04 years. This duration may not capture late-onset complications. However, we believe the data still provide valuable insights into CoCHR, particularly in females and patients with smaller head sizes, as failures typically occur within the first three years postoperatively.^{5,10} Most limitations were mitigated by analyzing the entire population undergoing treatment across diverse locations and surgeons and comparing our findings with those from large-scale studies and registry-based evidence. In addition, this cohort will be followed longitudinally to enable ongoing assessment of long-term outcomes. Squeaking and noise were not formally documented; however, no significant concerns regarding these issues were raised during clinic follow-ups.

In conclusion, 128 hips that reached five-year follow-up had 98.0% survival. This aligns with or exceeds many reports of MoMHR. The absence of sex and head size effects on revision rates supports the robustness of CoCHR across different patient demographics and implant configurations. Given these favourable short- to mid-term outcomes, hybrid CoCHR could represent a viable alternative for patients seeking bone-preserving hip arthroplasty. Longer-term data will be essential to confirm these early results.



Take home message

- Hip resurfacing offers excellent functional outcomes and preserves bone stock, but is traditionally associated with higher revision risks in females and smaller component sizes.
- Hybrid ceramic-on-ceramic hip resurfacing (CoCHR) achieved 98.0% survival up to five years, showing no significant impact of sex or head size on outcomes, positioning it as a reliable option for diverse patients.
- Hybrid CoCHR significantly improved Oxford Hip Scores and University of California, Los Angeles activity scores regardless of sex and femoral head sizes.

Supplementary material



Table of individual patient reasons for revision ceramic-on-ceramic hip resurfacing.

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