■ HIP

Hip resurfacing for osteonecrosis

TWO- TO 18-YEAR RESULTS OF THE CONSERVE PLUS DESIGN AND TECHNIQUE

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Aims

Hip resurfacing arthroplasty (HRA) is an alternative to conventional total hip arthroplasty for patients with osteonecrosis (ON) of the femoral head. Our aim was to report the long-term outcome of HRA, which is not currently known.

Patients and Methods

Long-term survivorship, clinical scores and radiographic results for 82 patients (99 hips) treated with HRA for ON over a period of 18 years were reviewed retrospectively. The mean age of the 67 men and 15 women at the time of surgery was 40.8 years (14 to 64). Patients were resurfaced regardless of the size of the osteonecrotic lesion.

Results

The mean clinical follow-up was 10.8 years (2 to 18). The mean University of California, Los Angeles hip scores at the last follow-up were 9.3, 9.4, 9.2 and 6.8 for pain, walking, function and activity, respectively. A total of six hips underwent revision surgery, four for loosening of the femoral component and two for loosening of the acetabular component. Using any revision as an end point, the 15-year Kaplan-Meier survivorship was 90.3%. There were no wear-related failures. There were no femoral failures among the hips reconstructed with a cemented metaphyseal stem. A total of five hips showed narrowing of the femoral neck; all stabilised and remain asymptomatic, 21 showed signs of femoral neck impingement.

Conclusion

To our knowledge, this is the first report of a series of HRA performed for ON with 15-year survivorship. Our data confirm that patients with advanced stages of ON of the femoral head are excellent candidates for HRA.

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The treatment of disorders of the hip secondary to osteonecrosis (ON) of the femoral head remains controversial. There is, however, agreement about the need for prosthetic replacement in the advanced stages of the disease (Ficat stages III and IV).[1] Historically, the survivorship and outcome of conventional total hip arthroplasty (THA) have been poor in comparison with those of other diagnoses,[2-6] in particular among younger patients.[7] However, recent authors have reported higher rates of survivorship, owing to improvements made in the fixation of the femoral component[8-10] and the wear properties of the bearings.[11-13] The typical candidates requiring THA for advanced ON, are young and are likely to require revision surgery during their lifetime, suggesting a treatment strategy based on bone conservation such as hip resurfacing arthroplasty (HRA). Modern designs of resurfacing have been in use since the late 1990s and several authors have reported encouraging short- to mid-term results with HRA in patients with ON of the femoral head,[14-18] while others found ON to be a poor indication for HRA.[19] No long-term reports of the outcome following HRA for ON have been published.

The purpose of this study was to investigate the long-term clinical outcomes, survivorship and radiographic results of a large consecutive series of patients treated with metal-on-metal (MoM) HRA for Ficat stage III or IV ON of the femoral head.

Materials and Methods

Between 1996 and 2013, 82 patients (99 hips) with advanced (Ficat stage III or IV) ON of the hip underwent MoM HRA by the senior author (HA), a designer of the device used in this study. There were 67 men (82%) and 15 women (18%). Their mean age was 40.8 years

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Table I. Demographic characteristics of the patients

	Whole group	Men	Women
Age at surgery (yrs) (range)	40.8 (14 to 64)	42.8 (14 to 64)	32.9 (14 to 51)
Weight (kg)	81.8 (46 to 116)	86.7 (57 to 116)	61.8 (46 to 91)
Height (m)	1.76 (1.48 to 1.98)	1.79 (1.65 to 1.98)	1.62 (1.48 to 1.75)
Body mass index	26.3 (17.6 to 41.1)	26.9 (19.2 to 41.1)	23.5 (17.6 to 35.5)
Femoral head size after HRA (mm)	46.6 (36 to 54)	48.0 (42 to 54)	41.3 (36 to 50)
Angle of Revell[17] (°)	122.6 (75 to 202)	122.7 (75 to 202)	121.8 (85 to 164)

HRA, hip resurfacing arthroplasty

(14 to 64) (Table I) (a subset of this group was used in a previous publication; 70 patients, 85 hips).[14]

Resurfacing was undertaken regardless of the size of the necrotic lesion, if there was at least 1 cm of the height of the femoral head remaining after debridement of all necrotic bone. Our aim was to maximise the surface of the bone which was available for fixation, especially when there were large defects in the chamfered area. A few small defects extending into the cylindrical area were also accepted. The diameter of the femoral head and neck of both the operated and the contralateral hip were measured using a digital system (Image J version 1.41, National Institutes of Health), on the post-operative radiographs in 61 patients (122 hips), for whom this measurement may be. It has been suggested that too much reduction of the head to neck ratio at surgery may be associated with pseudotumor formation and subsequent revision.[20] The bony outline of the contralateral femoral head was measured and compared with the outside diameter of the femoral component which had been used. The mean diameter of the resurfaced femoral heads was 1.5 mm smaller than the diameter of the contralateral femoral head (46.6 mm (36.0 to 54.0) *versus* 48.1 mm (36.7 to 56.7), Student's *t*-test, p = 0.0231). The mean head to neck ratio was 1.34 (1.18 to 1.52) for the resurfaced hips and 1.41(1.26 to 1.62) for the contralateral hips. This difference was also statistically significant (Student's *t*-test, p = 0.0001).

During this period of time, the senior author also implanted 30 MoM HRAs in 24 very young patients with Ficat stage II or III ON, who had sufficiently good remaining acetabular articular cartilage,[21] and performed 16 conventional THAs in 15 older patients with advanced ON stages who either chose not to undergo resurfacing or could not for technical reasons such as having nonunion of the head-neck junction.

A total of 78 hips were Ficat stage IV and 21 were stage III. A total of 45 patients (55%) had unilateral ON and 37 (45%) had bilateral ON. In all, 31 patients had surgery to the contralateral hip including 19 MoM HRAs, two THAs, three hemi-resurfacings, and seven core decompressions. A total of 35 hips (35%) had previous surgery before MoM HRA, including core decompression (20), pinning (nine), hemi-resurfacing (three), free vascularised fibular graft (two) and a Judet graft (one).[22] Risk factors for the development of ON included steroids (34 hips), trauma (22), alcohol (seven) and sickle-cell disease (two). The ON was idiopathic in 34 hips.

The prosthesis used was the Conserve Plus hip resurfacing system (Microport Inc., Arlington, Tennessee), a device approved by the United States Food and Drugs Administration. This system features a one-piece acetabular component made of cobalt and chromium, double heat-treated, and solution annealed. Its outside dimension is 170°. The cover of the head by the acetabular component ranges from 158.9° for a 36 mm diameter head to 163.3° for a 60 mm diameter head. This cover is similar to that of the Birmingham Hip Resurfacing (BHR) (Smith & Nephew, London, United Kingdom) in large sizes but greater in the small sizes and substantially greater than that of the recalled ASR device (Depuy Orthopaedics, Warsaw, Indiana) in all sizes. The clearance between the femoral and acetabular components ranges from 80 µm to 220 µm. Detailed descriptions of the surgical technique used for implantation of the device have been previously published.[23,24] Residual femoral defects were photographed at the end of preparation of the femoral head and their size was recorded. In all, five hips had no defects and three of these were reamed so that the length of the neck was shortened by 0.5 cm. A total of eight had defects < 1 cm in size, 42 had defects between 1 cm and 2 cm in size and 44 had defects > 2 cm in size. Improvements in the surgical technique were made over time and have been previously described.[25,26] These included a thorough debridement of all necrotic bone, maximising the surface area for fixation with drill holes, optimising bone preparation with Jet lavage and Co2 blow dry (Carbojet, Kinamed Inc., Camarillo, California) and maintaining a dry surgical field with both dome and intertrochanteric suction. The metaphyseal stem was cemented in 56 hips (57%),[27] with the objective of increasing the area of the bone-cement interface. The indications for cementing the stem have also been previously described[28] and evolved over time, following four phases: initially, only hips with large femoral defects had a cemented stem, then all stems were cemented, then all stems were uncemented. Finally, stems were cemented for patients receiving small femoral components (< 48 mm) or having large femoral defects (or both). As a consequence, the hips with a cemented stem had slightly more femoral defects and larger angles of Revell,[17]

Table II. Characteristics of the hips reconstructed with and without cementing of the metaphyseal stem

Characteristics	Hips with uncemented stem (n = 43)	Hips with cemented stem (n = 56)	p-value
Age at surgery (yrs) (range)	40.9 (16 to 58)	40.7 (14 to 64)	0.9502 (Student's *t*-test)
Patient Weight (kg)	84.4 (52 to 116)	79.3 (46 to 111)	0.1311 (Student's *t*-test)
Femoral head diameter (mm)	46.3 (36 to 54)	46.9 (36 to 54)	0.4759 (Student's *t*-test)
Head defects > 1 cm (%)	79	93	0.4657 (chi-square test)
Angle of Revell (°)	119.7 (83 to 180)	124.9 (75 to 202)	0.2812 (Student's *t*-test)

Table III. Mean clinical scores (range) of the whole cohort

		Pre-operatively	Last clinical review	p-value
UCLA (Wilcoxon signed-rank tests)	Pain	3.6 (1 to 8)	9.3 (3 to 10)	0.0001
	Walking	5.8 (2 to 10)	9.4 (4 to 10)	0.0001
	Function	5.3 (1 to10)	9.2 (4 to 10)	0.0001
	Activity	4.2 (1 to 8)	6.8 (3 to 10)	0.0001
SF-12 (Student's paired *t*-tests)	Physical	31.7 (18.9 to 56.8)	49.1 (22.2 to 61.4)	0.0001
	Mental	43.3 (12.9 to 66.8)	50.0 (15.7 to 64.2)	0.0003

UCLA, University of California, Los Angeles; SF-12, Short-Form 12

although these differences were not significant (Table II). The cement used was Simplex P (Stryker, Kalamazoo, Michigan), which was refrigerated prior to surgery to increase the setting time (10 minutes to 14 minutes) so that it could be manually pressurised into all the defects. The Conserve Plus technique recommends a 1 mm cement mantle which facilitates seating of the component before the acrylic sets. This design and technique contrast with those of the BHR for which a much thinner or non-existant cement mantle and the use of cement in a more liquid state are advocated in order to seat the femoral component.[29]

The patients were followed up four months after surgery and then annually for the first five years, then every two or three years. Those who could not come to our main clinic were asked to attend at satellite clinics held each year in other cities within the United States. Some were reviewed by a local orthopaedic surgeon, who sent us the most recent radiographs and the patients were contacted for a telephone interview. Those who did not participate in any of these forms of follow-up were contacted by telephone to establish that the implants had not been revised. All patients completed a questionnaire and were evaluated using the University of California, Los Angeles (UCLA) hip scoring system,[30] quality of life surveys (Short-Form 12 (SF-12))[31] and plain radiographs. Pre-operative anteroposterior radiographs were used to measure the angle of Revell.[17] Post-operative anteroposterior radiographs were used to measure the metaphyseal stem to shaft angle and the abduction and anteversion angles of the acetabular component which were determined with Einzel-Bild-Roentgen-Analyse (EBRA-Cup version 2003, University of Innsbruck, Austria).[32] Contact patch to rim distance (CPR) was computed as previously described.[33,34]

The latest follow-up radiographs were compared with previous films by both investigators to detect periprosthetic radiolucencies, signs of impingement[35] and narrowing of the femoral neck.[36,37] The serum cobalt and chromium levels were measured in 29 patients as part of several prospective studies, or because they had a CPR distance of < 10 mm or, in one case, because there was radiographic evidence of impingement. If revision was undertaken, the components were sent to Dr. Patricia Campbell at the J. Vernon Luck Orthopaedic Research Center, Los Angeles, for analysis of the mode of failure.

Statistical analysis. Wilcoxon signed-rank tests were used for the comparison of pre- and post-operative UCLA hip scores and paired *t*-tests were used for comparison of pre- and post-operative SF-12 scores. Kaplan-Meier survival estimates were computed using the time to revision for any reason as the end point. The log-rank test and the Cox proportional hazard ratio were used to identify risk factors for aseptic failure of the femoral component. Statistical significance was set at $p = < 0.05$. All statistical procedures were performed with Intercooled Stata 6.0 (Stata Corp., College Station, Texas).

Results

In all, three patients died of causes unrelated to the surgery at four, six and ten years after surgery. One patient was lost to follow-up and two did not have a formal follow-up visit at 24 months or later but had not undergone further surgery, yielding a loss to follow-up quotient of 0.5 (3/6). We believe this confers ample reliability to the survivorship analysis.[38] The clinical and radiographic status of these two patients was excellent at the time of their last visit. The mean clinical follow-up was 10.8 years (2 to 18), with 27 hips (24 patients) followed for > 15 years. The mean radiographic follow-up was 8.9 years (4 months to 17.3 years). All clinical scores significantly improved from the pre-operative levels (Table III).

Table IV. Details of the patients who underwent revision surgery

Hip ID	Gender	Age (yrs)	Aetiology	Time to revision (mths)	Cemented stem	Ficat stage	Previous surgery	Head size (mm)	Reason for revision	Femoral defects size (cm)	Angle of Revell (°)	Component abd. angle (°)	Component ant. angle (°)	CPR distance (mm)
6	M	53	Idiopathic.	23.4	No	IV	None	52	FL	>2	109	42.8	7.6	19.9
25	F	49	Alcohol	61.7	No	IV	None	40	FL	1 to 2	94	46.4	29	8.5
307	F	31	Steroids	178.6	No	IV	None	36	FL	1 to 2	129	48.1	16.5	11.5
455	M	16	Trauma	85.1	No	III	None	44	FL	None	83	38	19	14.6
629	F	43	Idiopathic	56.4	Yes	IV	None	42	AL	1 to 2	124	33.2	16.2	15.7
856	M	24	Alcohol	108.9	Yes	III	Hemi-resurfacing	50	AL	1 to 2	122	57.4	16.2	11.7

FL, femoral component loosening; AL, acetabular component loosening

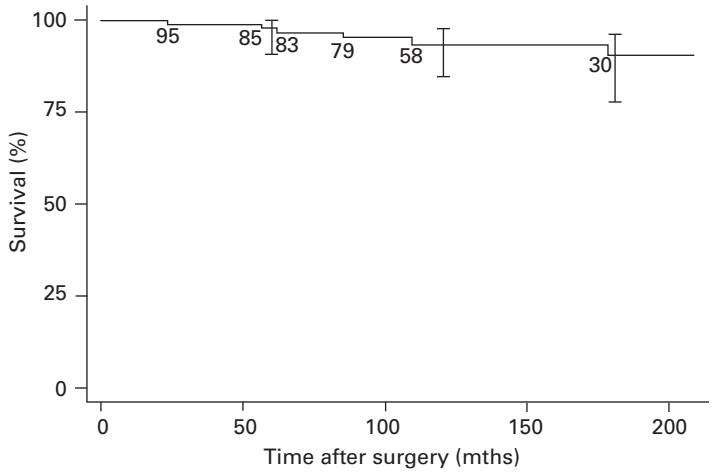

Fig. 1

Kaplan-Meier survivorship of hip resurfacing for osteonecrosis. The time to any revision was used as the end point. Brackets represent the 95% confidence intervals at five, ten and 15 years after surgery. The number of hips at risk is indicated.

A total of 51 patients (62%) returned to sporting activities and eight (10%) engage regularly in impact sports. The post-operative SF-12 physical and mental scores were comparable to those of the general population of the United States[39] (Student's *t*-tests, p = 0.3388 and p = 0.9628, respectively).

There were no intra- or post-operative complications. A total of six hips (six patients) underwent revision surgery (Table IV). The indications for revision included aseptic femoral loosening in four hips, at one, five, seven and 15 years post-operatively, respectively, and aseptic acetabular loosening component in two hips, at five and nine years after resurfacing. There were no wear-related revisions. Using the time to revision for any reason as the end point, Kaplan-Meier survival estimates were 97.7% (95% confidence intervals (CI) 91.0 to 99.4) at five years, 93.5% (95% CI 84.9 to 97.3) at ten years and 90.3% (95% CI 77.9 to 95.9) at 15 years (Fig. 1).

None of the hips resurfaced with a cemented metaphyseal stem had aseptic failure (log-rank test, p = 0.0719). There was no association between the size of the femoral defect and failure of the femoral component (Cox proportional hazard ratio, p = 0.343) nor between the angle of Revell and failure of the femoral component (Cox proportional hazard ratio, p = 0.133).

A total of five hips (four patients), had narrowing of the femoral neck by > 10%. In four of these hips, the metaphyseal stem was uncemented and one had a cemented stem. All five patients remain asymptomatic. The narrowing stabilised at a mean of 26 months (19 to 59) post-operatively. A total of 21 hips (20 patients) showed radiographic signs of femoral neck to component impingement. In 11 hips, these signs were on the superior aspect of the neck, six were on the posterior aspect, three on both the superior and posterior aspects and one on the anterior aspect of the neck. All but two of these patients were asymptomatic, one underwent revision surgery for acetabular loosening and one has a UCLA pain level of five, the cause for which has not been identified, 12 years after resurfacing. The serum levels of cobalt and chromium were normal and metal artifact reduction sequence (MARS) MRI scans were unremarkable.

One patient, with bilateral resurfacings, with a Conserve Plus on the left side and an ASR prosthesis (Depuy, Warsaw, Indiana) on the right side developed an adverse local tissue

Table V. Long-term survivorship of total hip arthroplasty (THA) for osteonecrosis in the literature

Author	Year	Journal	Implant	n	Survivorship	Comments
Kim et al[44]	2005	*Acta Orthop*	HG1	65	*70%* at 15 yrs	The component showed better durability than the stem
Kim et al[8]	2011	*JBJS Am*	Cementless and hybrid THA	148	*83%* cementless and *85%* hybrid, 98% stem survival at 18 yrs	Wear and osteolysis caused most revisions
Solarino et al[45]	2012	*J Orthop Traumatol*	Alumina bearing	68	> *95%* at 15 yrs	No femoral component aseptic loosening
Australian Orthopaedic Association National Joint Replacement Registry[46]	2014	*Online publication*	All THA	9019	*91.1%* at 13 yrs	
Kim et al[47]	2013	*J Arthroplasty*	S-ROM	64	*93.8%* femoral at 16 yrs	21% failure on the acetabular side (polyethylene wear)
Bedard et al[48]	2013	*J Arthroplasty*	Mix of cementless THA	80	*93%* at 10 yrs	Cementless stems better than cemented-6 wear, 2 periprosthetic fractures, 3 other
Cheung et al[10]	2015	*Hip International*	Omnifit HA coated	117	*97.1%* at 19 yrs	Aseptic loosening used as end point – 6% with thigh pain

reaction (ALTR)[40] on the right side, which was identified on MARS MRI scanning. The left hip was asymptomatic. No patient developed symptomatic ALTR associated with the Conserve Plus device. The mean abduction angle of the acetabular component was 42.9° (24° to 59°) and the mean anteversion of the acetabular component was 16.1° (3° to 36°). The mean CPR distance was 15.0 mm (8.2 to 23.7). This distance was < 10 mm in nine hips. Among the 29 patients (15 with unilateral and 14 with bilateral MoM HRAs) in whom the serum levels of metal ions were measured, none had elevated cobalt or chromium ions, as defined by the guidelines of the Medicines and Healthcare Products Regulatory Agency of the United Kingdom[41] except the patient who had the contralateral ASR prosthesis (Co 10.4 µg/L and Cr 7.5 µg/L). The median level of cobalt was 1.5 µg/L (interquartile range (IQR) 1.1 to 2.3) and the median level of chromium was 2.0 µg/L (IQR 1.4 to 3.8) for the patients with unilateral implants. The median level of cobalt was 1.9 µg/L (IQR 1.1 to 7.0) and the median level of chromium was 2.0 µg/L (IQR 1.5 to 5.2) for those with bilateral HRAs.

Discussion

Patients with ON of the hip are usually young and age itself may justify the use of a bone-conserving prosthetic solution for those with advanced stages of the disease. Clinical data on the long-term benefits of HRA in these patients are still scarce and we sought to report the long-term clinical results of a large series of patients treated with MoM HRA for Ficat stage III or IV ON of the femoral head.

The main limitation of this study comes from the extended time period over which patients were treated (more than 16 years), which could have affected the homogeneity of the clinical and radiographic data collected at the last follow-up. However, our previous study (which includes eight patients from this manuscript) has shown that pain relief, mobility and quality of life are maintained over time in patients treated with HRA,[42] and the radiographic features investigated in this study (femoral neck narrowing and signs of impingement) are known to develop within the first few years after surgery.[35-37,43] In addition, the results reported in this study may be specific to the Conserve Plus design, in particular when the metaphyseal stem is cemented as this technique may not be suitable when the cement is applied in its liquid state because cement in this state may not fill all of the defects to their depth or could expand much further into the cancellous bone surrounding the stem, possibly increasing the risk of thermal necrosis. In addition the cement may take longer to set, allowing more blood at the interface. A dry bone-cement interface lessens the chances of a fibrous fixation, which could lead to component loosening. The overall 15-year survivorship was 90.3% in this series. This compares favourably with most previously reported long-term outcome studies of THA undertaken for ON (Table V).[8,10,44-48]

Historically, the long-term fixation of the femoral component was the main cause of concern in THA for ON. The more recent use of articulations with low rates of wear may reduce the rate of failure due to osteolysis related to polyethylene debris.[11-13] Our series shows that, with proper preparation of the femoral head and cementing of the metaphyseal stem (at least in patients with small components and heads with large defects), HRA can achieve rates of survival comparable with the best modern THAs (Fig. 2). The hips that failed on the femoral side were resurfaced during the development phase of the femoral preparation and cementing technique. We did not find any association between the extent of the necrotic lesion and the survivorship of the femoral component even when there were large defects including some in the chamfered area of the head (Fig. 3). These findings are in agreement with those of Nakasone et al.[49] However, the cementing of the metaphyseal stem specifically proved effective in preventing aseptic loosening of the femoral component in this study. This confirms the value of this technique, as already reported for other diagnoses.[27] It is important to stress that all the

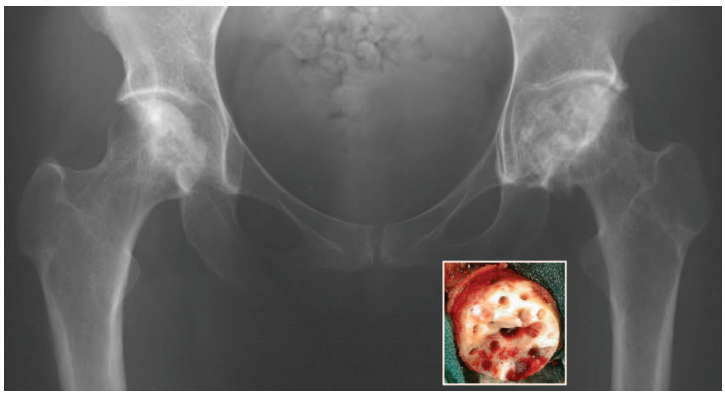

Fig. 2a

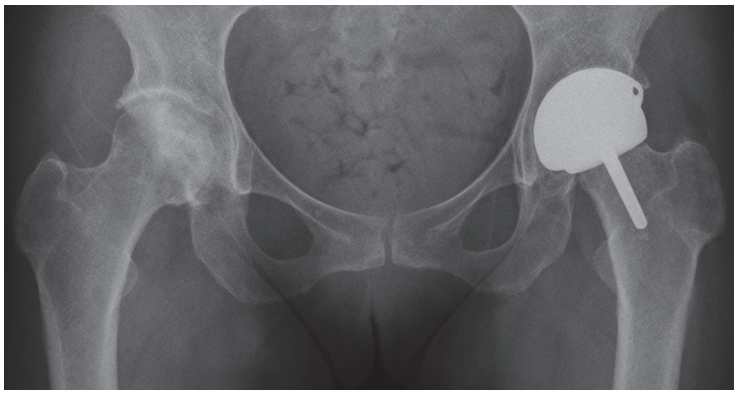

Fig. 2b

a) Anteroposterior radiograph of a 38-year-old woman with Ficat stage IV osteonecrosis of the left hip. Femoral defects larger than 2 cm extended into the cylindrically reamed portion of the femoral head (inset); b) the metaphyseal stem of the 38 mm femoral component was cemented and the patient is shown 15 years after surgery. The inclination of the acetabular component was 37.5° and the anteversion was 25.5°, and the contact patch to rim distance is 10.3 mm. The University of California, Los Angeles scores were 9, 10, 10, and 6 for pain, walking, function and activity, respectively.

necrotic bone should be removed, the head should be vigorously jet-lavaged and dried with both femoral and intertrochanteric suction, prior to cementation with doughy pressurised cement, to produce a cement mantle of at least 1 mm. We recommend the use of CO2 blow dry with the Carbojet (Kinamed, Camarillo, California). The more recent failures in this series were caused by aseptic loosening of the acetabular component in two patients with fibrous fixation. A 43-year-old woman had a combination of mild developmental dysplasia of the hip (Crowe Grade I)[50] and Ficat stage IV ON. The acetabular component was positioned with a lateral opening of 33° and was uncovered laterally by about 20%. The acetabulum was reamed to the true floor and the 52 mm acetabular component, which appeared to be osteointegrated on radiographic follow-up, loosened 56 months post-operatively. This was possibly secondary to acetabular over–reaming. A smaller component may have been preferable, based on the analysis of the sectioned femoral head which revealed a thick cement mantle. The second patient was a 24-year-old man with alcohol-induced bilateral Ficat stage IV ON. The side with the most advanced damage was treated with total HRA while the contralateral hip was treated with a hemi-resurfacing, using the same size Conserve plus 50 mm femoral component. This initial hemi-resurfacing component was somewhat undersized for the acetabulum, the remaining acetabular cartilage quickly thinned and the hip became increasingly painful. The acetabular component was added at revision one year post-operatively. The patient's UCLA pain score improved to ten but the acetabular component loosened after a further eight years and required further revision to a conventional THA. Today both hips would have undergone full HRA initially. Our indications for hemi-resurfacing have changed during the study period from initially patients aged < 50 years, to 40, then 30 years and now, following this study we no longer recommend hemi-resurfacing at any age, but would suggest full HRA in all younger patients. The clinical scores in this study showed excellent pain relief and restoration of quality of life. The UCLA hip scores which were achieved are

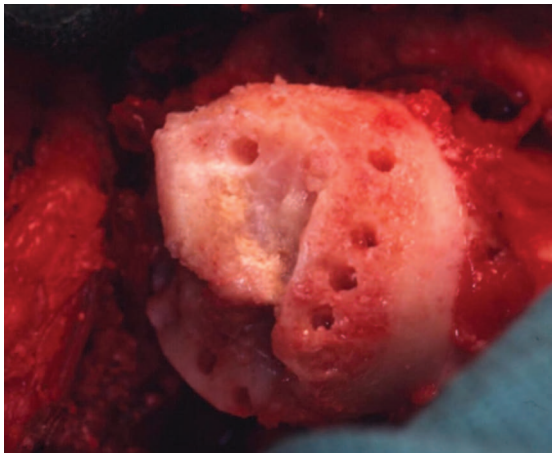

Fig. 3a

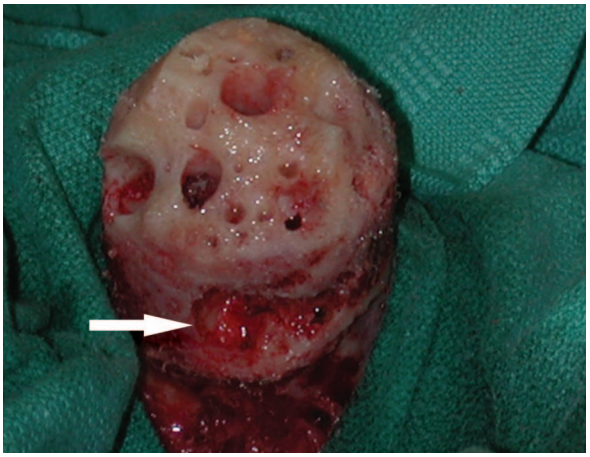

Fig. 3b

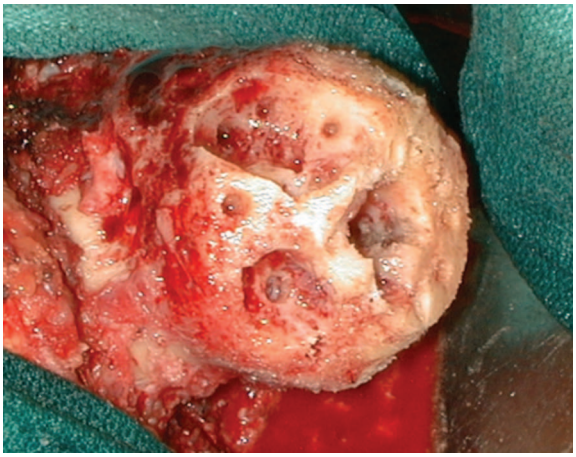

Fig. 3c

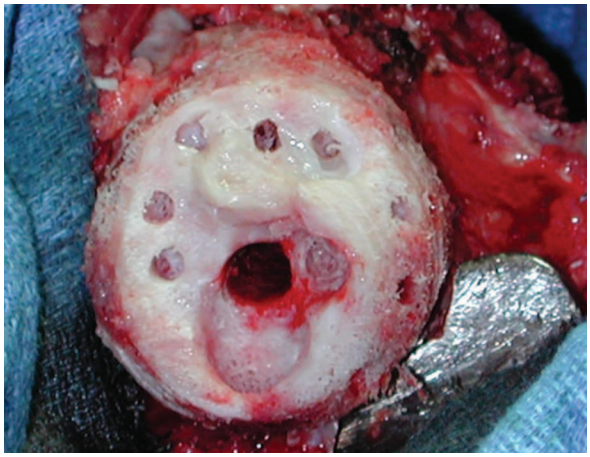

Fig. 3d

Photographic examples of femoral heads resurfaced in this series with large defects. The photographs were taken after reaming of the femoral head was complete, before cementation of the femoral component: a) the right hip of a 52-year-old man with bilateral steroid-induced osteonecrosis (ON), now 15 years post-operatively. University of California, Los Angeles (UCLA) scores were 8, 9, 8 and 6 for pain, walking, function and activity, respectively; b) the right hip of a 45-year-old man with bilateral idiopathic osteonecrosis who had previously undergone core decompression. Note the large femoral defect in the cylindrically reamed area of the head (arrow). At 14 years post-operatively, the UCLA hip scores were 9, 10, 10 and 8 for pain, walking, function and activity; c) a 46-year-old man with post-traumatic ON who had previously undergone pinning. At 15 years post-operatively, the UCLA scores were, 8, 10, 10 and 7 for pain, walking, function and activity, respectively; d) a 14-year-old woman with post-traumatic ON who had previously undergone pinning and then a free vascularised fibular graft. Now ten years post-operatively the UCLA scores were 8, 9,10 and 6 for pain, walking, function and activity.

comparable to those in patients with other aetiologies, with the exception of the activity level, which is about 0.5 points lower, as the youngest patients with large defects were advised against impact activities.[14]

Narrowing of the femoral neck of > 10% was observed in five hips and this prevalence was lower than those reported previously.[36,43] It appears that the aetiology of ON does not lead to modification of the transfer of stress through the femoral head and neck that could be responsible for these radiographic changes. The prevalence of radiographic signs of impingement was the same as has been previously reported for patients with other aetiologies[35,51] and does not seem to have any influence on pain relief or survivorship.

To our knowledge, this is the first long-term outcome study of a series of HRAs performed for ON with survivorship data at 15 years post-operatively. Our data confirm that patients with advanced ON of the femoral head are excellent candidates for HRA. There were no femoral fractures or loosening, when the metaphyseal stem was cemented. We are now encouraged with the prospect of enduring durability, as the current mean age of these patients at the time of writing is 54 years (17 to 71). One of the most interesting findings is the durability of femoral fixation despite large defects, a result we attribute to the design and technique as well as the normalised compression stresses inherent to the resurfacing concept. In addition, the hips have excellent clinical results, which have not deterio-

rated with time and have shown no evidence of symptomatic ALTR. Although nine hips have a CPR distance between 8.2 mm and 10 mm, none have substantially elevated serum levels of cobalt or chromium ions or any symptoms. The advantages of bone preservation, stability and the ability to easily convert to THA coupled with the absence of problems relating to the taper are the hallmarks of success in HRA. Even if the acetabular component has to be revised, the relatively smooth back side of the Conserve Plus prosthesis with no prominent flanges, allows removal with minimal loss of bone. We believe that the excellent results achieved in this study of young patients presenting with ON of the hip can be attributed essentially to the cementing technique of the Conserve Plus design with manual application of cement in its doughy stage, which permits a cement mantle of > 1 mm and the cementing of the metaphyseal stem in hips with small sizes and large defects.

Take home message:

Patients with ON of the femoral head are excellent candidates for long-term success of hip resurfacing arthroplasty.

Author contributions:
H. C. Amstutz: Data collection, Performed surgeries, Editing the paper.
M. J. Le Duff: Data collection, Data processing, Statistical analysis, Writing the paper.

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