Risk Factors Affecting Outcome of Metal-on-Metal Surface Arthroplasty of the Hip

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Abstract: We evaluated radiologic and clinical features affecting the outcome of hybrid metal-on-metal surface arthroplasty of the hip in 119 hips in patients 40 years and younger. Only the hips that had either failed or had minimum 2-year followup were reviewed. Ninety-four hips in 83 patients with a mean age of 34.2 years (range, 15–40 years) were reviewed. Seventy-one percent of the patients were males and 29% of the patients were females; 14% had previous surgery. The Chandler index and surface arthroplasty risk index were calculated. The mean followup at 3 years (range, 2–5 years) showed that three hips were converted to a total hip replacement at a mean of 27 months (range, 2–50 months) after the original surgery, and 10 hips had significant radiologic changes. The mean surface arthroplasty risk index for these 13 problematic hips versus the remaining hips was significantly higher, 4.7 and 2.6, respectively. The mean angle between the prosthesis stem and femoral shaft in the problematic group was significantly smaller than in the remaining hips: 133° and 139°, respectively. With a surface arthroplasty risk index score greater than 3 the relative risk of early problems is 12 times greater than if surface arthroplasty risk index less than or equal to 3.

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The predictability of the results of THA has been shown to be excellent in the older age groups; however, when faced with a patient 40 years or younger, the longevity of the implant remains a concern with a failure rate ranging from 20% to 42%.[16,27,33,40] Unfortunately, the introduction of cementless designs has not led to a uniformly significant improvement in survivorship.[6,30] The difficulty is not in restoring function but in the long-term fixation of the THR, avoiding prosthetic escalation[13,23,45] and maintaining a functional hip for the patient.[34] When and if revision surgery becomes necessary, the degree of bone loss determines the success of that subsequent intervention.[17,45] This loss of bone stock has been attributed mainly to wear debris-induced osteolysis and subsequent loosening of the prosthesis.[35] Because increased acetabular wear has been correlated to increased risk of implant loosening,[40] the orthopaedic community has attempted to minimize implant wear with the use of alternate bearing surfaces. Another approach is to preserve as much bone as possible at the initial intervention such as hip arthrodesis, but its indications remain limited.[7]

To address these difficulties, new hip implant designs now are being used to maximize bone stock preservation and minimize the morbidity of revision surgery.[1,31,32] However, there is a deficiency in the literature for identifying patients who are suitable candidates for these more conservative solutions on the femoral side which rely on different and lesser areas of fixation than the standard THR. Although the Chandler index initially published in 1981[10] has been used to identify patients with THRs at risk of failing, its applicability to different prosthetic designs and current THR is unknown. For surface arthroplasty, because of its recent reintroduction with a metal-on-metal bearing, there currently exist no guidelines to optimize patient selection and implant survivorship. A hybrid design was adopted based on our experience with cementless metal-on-polyethylene surface arthroplasty where the principal mechanism of failures was aseptic femoral loosening.[5]

The purpose of the current study was to evaluate the early outcome of a hybrid metal-on-metal surface arthroplasty of the hip in a patient population (40 years and younger) which has the most to gain from a more conservative prosthetic solution, and to identify potential risk factors.

MATERIALS AND METHODS

The criteria for inclusion in the study were age of 40 years or younger at the time of surgery, minimum followup of 2 years, or conversion surgery. Of the patients 40 years and younger among the 589 patients who received metal-on-metal surface arthroplasty of the hip, 83 patients (94 hips) fulfilled these criteria with all surgeries done by the senior author. Twenty-seven prostheses were implanted in females and 67 prostheses were implanted in males. The mean age of the pa-

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tients at surgery was 34.2 years (range, 15–40 years). The preoperative diagnoses for these 94 hips are shown in Table 1. Of these hips, 14% had previous surgeries. All patients were evaluated preoperatively and at latest followup using the Short-Form Health Questionnaire-12[44] and University of California Los Angeles hip score.[2] For the latter, a score of 1 to 10, with the latter being the best score, is given for pain, walking, function, and activity. The ROM was measured in all hips by one of the authors. The Charnley Class[11] and patient weight also were recorded. All patients were graded according to the index of Chandler et al.[10]

Development of the Surface Arthroplasty Risk Index

The initial Chandler index included six factors each given one point: absence of collagen disease, osteonecrosis (ON), previous surgery, activity of the ON patient, unilateral or bilateral involvement, and weight of the patient (Table 2). An univariate analysis of all independent variables (diagnosis, gender, weight, activity level, previous surgery, femoral head cysts) and the six factors of the Chandler index was done to establish their relationship with radiologic changes or conversion surgery. Variables that had a significant relationship or previously had been identified as important were included in a multivariate analysis by logistic regression. For the surface arthroplasty risk index scoring, one or two points were assigned depending on the values of their odds ratio for the risk of failure. Based on this analysis and the distinct fixation of the femoral component in surface arthroplasty (resurfaced femoral head versus a stem into the intramedullary canal), absence of collagen disease and ON were replaced by giving two points to the presence of femoral head cysts greater than a 1 cm. One point was given for patients who had previous surgery to the resurfaced hip. With Charnley class correlated to activity ($p = 0.043$), and the latter being the main patient factor affecting wear,[18,37] the patient activity score was assigned one point and included in the surface arthroplasty risk index eliminating unilateral hip disease. To quantify the activity, the University of California Los Angeles activity score was used because it has been validated previously[38,46] with a score greater than 6 defined as intense. Patient weight less than 82 kg was given 2 points, based on the odds ratio and the association of lesser weight with a smaller femoral component ($r = 0.60$, $p = 0.00$); therefore 2 points were given to patients with a weight less than 82 kg.

TABLE 1. Preoperative Diagnoses

Etiologies	Percentage of Hips
Osteoarthritis	24.4%
Trauma	18.1%
Osteonecrosis	18.1%
Developmental dysplasia of the hip	19.1%
Rheumatoid diseases	6.4%
Slipped capital femoral epiphysis	4.3%
Legg-Calve-Perthes disease	6.4%
Ankylosing spondylitis	3.2%
Previous Surgeries	
Failed osteotomy	5.3%
Failed core decompression	6.4%
Failed hemiresurfacing	1.1%
Failed internal fixation	1.1%
Total	**13.8%**

TABLE 2. Items for the Chandler Index and Surface Arthroplasty Risk Index

Items	Chandler Index Scoring	Surface Arthroplasty Risk Index Scoring
Absence of collagen disease	1	–
Avascular Necrosis	1	–
Unilateral hip disease	1	–
Previous surgery	1	1
Weight	1 if >82 kg	2 if <82 kg
Activity level	1	1
Femoral cysts >1 cm	–	2

Radiographic Evaluation

Radiographic evaluation was done using AP and Johnson lateral radiographs. The angles between the stem and the anatomic axis of the femoral shaft on the AP radiograph were measured by an independent observer.[12] Evidence of radiolucent lines of greater than 1 mm was recorded for the acetabular socket using the zone of DeLee and Charnley[14] adding a fourth zone for the ischium. For the femoral side, three zones around the short stem were delineated (Fig. 1). Acetabular inclination was determined in relation to the inter-teardrop line. Femoral neck remodeling was assessed at the junction of the femoral component rim, looking for sclerotic lines or narrowing at that junction.

To assess the biomechanical reconstruction of the hip, the following measurements were made on the AP radiograph of the pelvis (Fig. 2) as described originally by Johnston and Larson[24] and applied to THR by Russotti and Harris:[36] femoral offset, and in Charnley Class A patients, the hip lever arm ratio (abductor moment arm divided by body moment arm) for both hips, were calculated. The hip axis length was measured preoperatively and postoperatively.[19]

Surgical Technique

A posterior approach was used in all but two patients for whom a trochanteric osteotomy was done. All components had

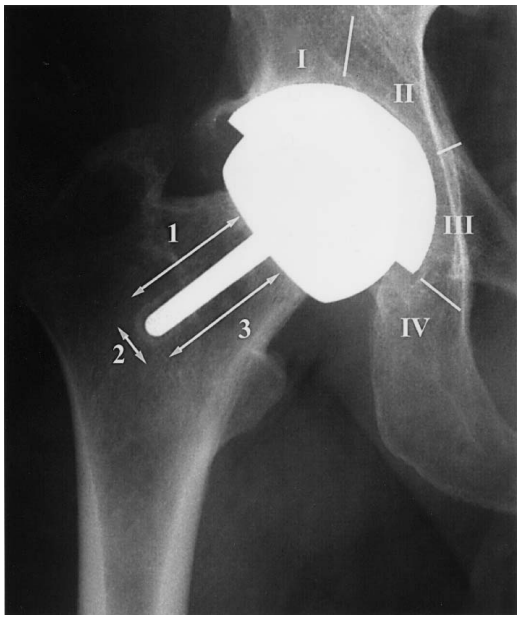

FIGURE 1. This radiograph shows the three femoral zones around the short stem. Radiolucencies can be seen in Zones 1 and 2. The four acetabular zones also are shown.

a metal-on-metal bearing with hybrid fixation from the same manufacturer (Conserve Plus®, Wright Medical Technology, Memphis, TN). The acetabular shell is hemispherical (170°) with a sintered porous coating for cementless fixation press fitted 1 mm in all cases. The femoral component is of the same design as the component used for hemiresurfacing arthroplasty[4] using a short stem to ensure accurate alignment with a uniform cement mantle around the resurfaced femoral head. However, the tolerances for sphericity and surface finish are significantly tighter to permit adequate diametral clearances for lubrification of the metal-on-metal bearing. The surgical technique has been described previously.[1] There are 10 sizes with the components available in 2-mm increments with a 10-mm difference in size between the acetabular (range, 46–64 mm) and femoral components (range, 36–54 mm). All components are made of a cast F75 CoCrMo alloy. In current series, the median femoral component size was 46 mm (range, 36–54 mm) and acetabular component size was 56 mm (range, 46–64 mm).

RESULTS

At a mean followup of 3 years (range, 2.0–5.6 years) with two patients (two hips) lost to followup, University of California Los Angeles hip scores improved significantly for pain (3.1 to 9.1), for walking (4.4 to 9.2), for function (5.8 to 9.1), and for activity (5.5 to 7.1) ($p = 0.00$). The Short-Form Health Questionnaire-12 improved significantly from 29.9 to 47.7 for the physical component and 44.8 to 51.5 for the mental component ($p = 0.00$). Range of motion improved from 79.5° to 116.2° for flexion and extension, 28.9° to 70.0° in abduction and adduction measured in extension, and 20.2° to 74.5° in rotation also measured in extension.

Conversions

Three patients had conversion to a THR: one after a femoral neck fracture at 2 months, one secondary to femoral component loosening at 29 months, and one secondary to persistent impingement and subluxation at 50 months. For the patient with loosening, the acetabular socket was left in situ using a unipolar femoral head on a stem device. The two other patients also had revision of the acetabular socket because of the unavailability of the unipolar femoral heads early in the series. Finally, one patient had late hematogenous sepsis develop and had a direct exchange at 36 months.

Chandler Index versus Surface Arthroplasty Risk Index

The mean index scores for the 13 problematic hips (three hips converted to THR and 10 hips with significant radiologic changes on the femoral side) versus remaining hips: 4.7 versus

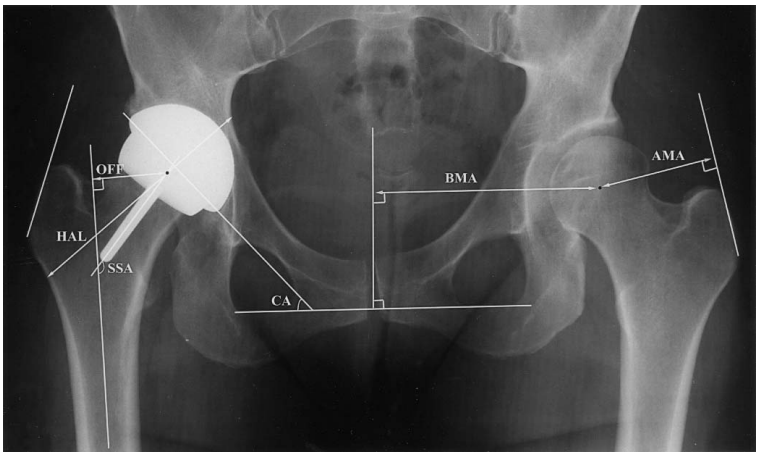

FIGURE 2. This radiograph shows the radiologic measurements for biomechanical analysis. OFF = femoral offset; HAL = hip axis length; AMA = abductor moment arm; BMA = body moment arm; CA = cup angle; SSA = stem shaft angle.

TABLE 3. Comparison of the Two Groups with a Metal-On-Metal Surface Arthroplasty

Items	Problematic Hips (13)	Well-Functioning Hips (79)	p Value
Percent previous surgery	46%	8.6%	0.001
Mean weight (kg)	71.6	83.9	0.016
Mean activity level	7.5	7.3	0.791
Percent with femoral cysts >1 cm	92%	53%	0.028
Median femoral component size (mm)	42	46	0.016
Mean Surface Arthroplasty Risk Index	4.7	2.6	0.001
Mean Chandler index	2.6	2.8	0.529

2.6 for the surface arthroplasty risk index ($p = 0.00$) and 2.6 versus 2.8 for the Chandler index ($p = 0.358$) (Table 3). In this series, weight of less than 82 kg was associated with having early radiologic changes and with a smaller femoral component ($r = 0.60$, $p = 0.00$). Male gender was not a significant factor in the problematic group ($p = 0.40$). Using a nonparametric comparison the surface arthroplasty risk index for the 13 hips with problems was significantly higher than the remaining 79 hips ($p = 0.001$), the same analysis for the Chandler index showed no significant difference ($p = 0.358$). There were no patients with a surface arthroplasty risk index less than 3 in the problem group. The pain score between the two groups was 9.2 for the problematic group and 9.3 for the remaining 79 hips ($p = 0.78$). Patients with a surface arthroplasty risk index greater than 3 had a relative risk to have early problems 12 times greater than patients with a surface arthroplasty risk index of 3 or less.

Biomechanical and Radiographic Evaluation

None of the acetabular components have shown migration or a complete radiolucent line in all three zones. Eight patients had radiolucencies around the short femoral stem, two of them with component migration into varus. Three hips (two patients) had narrowing of the femoral superolateral neck. The incidence of osteolysis was 2.1%; all were femoral lesions in Zone 1.

The biomechanical reconstruction measurements are summarized in Table 4. Using parametric analysis, the only factor independently related to the surface arthroplasty risk index was the stem shaft angle, which averaged 139° for the hips without problems versus 133° for the hips with problems ($p = 0.03$). The postoperative hip axis length was significantly smaller in the hips with problems (mean of 113 mm versus 129 mm for the hips functioning well ($p = 0.00$), but this was correlated directly with a lower weight ($r = 0.44$, $p = 0.00$). The mean hip lever arm ratios between operated (0.550) and nonoperated hip (0.553) in Charnley Class A patients were not significantly different ($p = 0.81$). The remaining factors had no association with the outcome: femoral offset ($p = 0.88$), hip lever arm ratio ($p = 0.36$), or cup angle ($p = 0.89$).

Complications

There were no neurovascular injuries in this series. Two patients with complications both required reoperation but no patients required conversions to a THR. One patient had a socket exchange because of component size mismatch during index surgery. One of two patients who had a transtrochanteric approach had surgery to resolve a trochanteric bursitis and has a painless trochanteric nonunion.

DISCUSSION

Total hip replacement had provided an incomplete solution to the problem of advanced hip arthritis in young patients.[6,10,16,43] Although pain relief and functional results are excellent, the advent of cementless fixation has not significantly improved survivorship results, which are inferior to 80% at 10 years.[16,20] Although improved medium-term results are being reported,[9] proximal femoral bone stock always is compromised after a THR because of actual removal of bone at the time of implantation and adaptive bone remodeling (stress shielding).[35] This becomes even more important for patients 40 years and younger who provide the most stringent test of the prosthesis and are at greatest risk of a second operation in their lifetime.[16,40] When Sochart[40] reported the long-term results of cemented THR for this patient age group, an annual wear rate

TABLE 4. Radiographic and Biomechanic Analysis

Radiographic Variables	Mean	SD
Stem shaft angle	138.2	9.2
Cup angle	41.8	6.7
Hip lever arm ratio (surgically treated)	0.55	0.1
Femoral offset	41.9	9.8
Hip axis length preoperative	137.3	20.3
Hip axis length postoperative	127.3	19.1

greater than 0.1 mm per year of the bearing surface was significantly correlated to osteolysis and the risk of acetabular and femoral component loosening. However, there still was a 28% incidence of implant failure despite an optimal wear rate of less than 0.1 mm per year. The patient profile of that series that showed the greatest risk of failure included males with either degenerative arthrosis or congenital dislocation. Interestingly, no patients with a diagnosis of ON having hip arthroplasty were included in that series.

The early clinical results seem promising for this surface arthroplasty with all patients returning to high functional and activity levels. With only three patients requiring conversion surgery, the early high failure rates (15%–33%) of cemented metal-on-polyethylene surface arthroplasty have been avoided[8,21,25] and these results are consistent with the overall series of metal-on-metal surface arthroplasty at a mean followup of 4.8 years.[5] When Kim and associates[27] reviewed the mid-term experience of cemented metal-on-polyethylene surface arthroplasty (THARIES, Zimmer, Warsaw, IN) in this patient population (40 years and younger), patients with noninflammatory arthropathy and patients younger than 30 years were six times more likely to have failure at 3 to 5 years with a survivorship of 63% at 3 years. In that series, the radiographic failures mainly were related to the all-cemented polyethylene socket. Because the polyethylene wear debris was such a dominating cause of failures in the metal-on-polyethylene surface arthroplasty,[3,22,26] other specific patient risk factors remained ill-defined.

Our results indicate that the surface arthroplasty risk index can be used to improve patient selection. This is critical especially in the absence of long-term data with this type of implant and where some patients would be best served by a standard THR. There still exists a lack of understanding on the location of the femoral head cysts and how it may impact femoral fixation, and the capacity of valgus positioning and cementation of the stem to improve fixation (Fig. 3). In the Chandler risk index[10] there was one point given to absence of collagen disease and ON both of which were replaced in the surface arthroplasty risk index by the femoral head cysts because femoral fixation is different in surface arthroplasty versus THR. Also, unilateral hip disease (Charnley Class A) was correlated significantly to University of California Los Angeles activity score greater than 6, which is why the activity score was included in the surface arthroplasty risk index and not unilateral hip disease. Interestingly, the weight showed an inversely proportional relationship to risk of ad-

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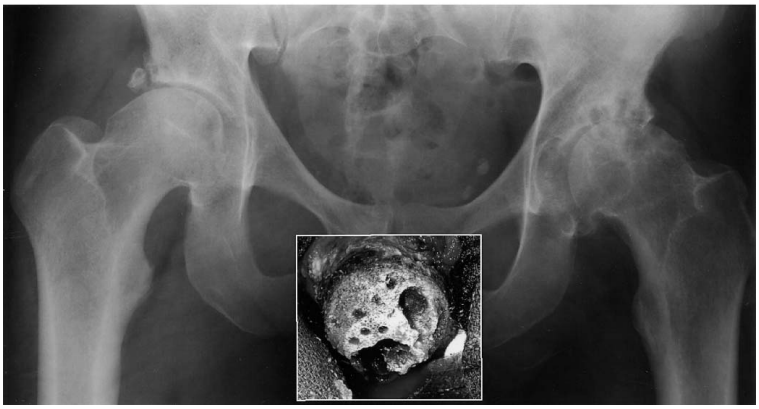

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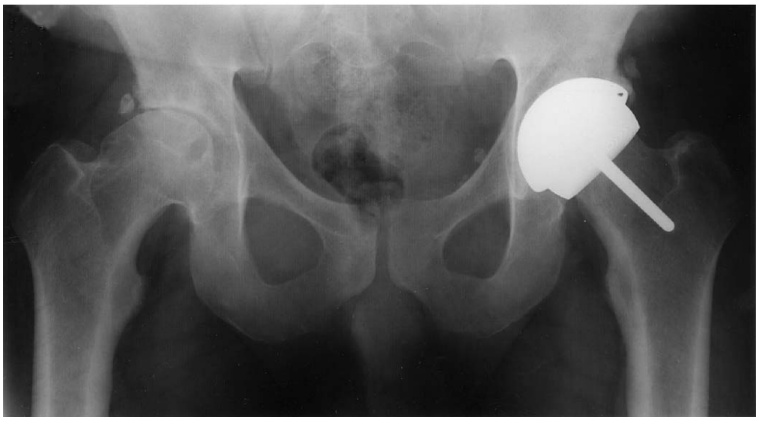

FIGURE 3A–B. (A) A preoperative AP radiograph shows a 38-year-old man with end stage OA. Multiple femoral cysts on the radiographs and the inserted intraoperative picture (inset) of the femoral head taken after preparation can be seen. (B) An AP radiograph taken 2 years after hybrid metal-on-metal surface arthroplasty of the hip shows no evidence of component loosening.

verse radiographic changes, or conversion, or both. This is explained by the fact that a weight less than 82 kg was significantly associated with a smaller femoral component size and a smaller fixation area. These data support previous findings with the THARIES metal-on-polyethylene surface arthroplasty where survivorship of smaller femoral components was significantly worse at 11 years followup compared with the larger sizes, 39% versus 59%, respectively.[28] Although this study focused mainly on the femoral side, the cementless acetabular socket seems to be performing well initially. However, longer followup is needed to assess better whether the metal-on-metal bearing will have a negative impact on fixation, through stress-shielding or wear debris-induced osteolysis. What is certain, the acetabular component size is comparable with cementless sockets in standard THR.[15,42]

Initial reports on second-generation metal-on-metal hip prostheses have showed a 60-fold decrease in volumetric wear debris production.[29,39] However, reduction of wear precludes good implant design and reliable fixation. This certainly is in accordance with the initial experience with metal-on-metal surface arthroplasty of the hip using the McMinn and Wagner components (Beaulé PE, Amstutz HC, Campbell PA, LeDuff M: Wagner and McMinn Metal-on-Metal Surface Arthroplasty of the Hip. Minimum five-year follow-up. Presented at the Canadian Orthopedic Association, London, Ontario 2001). At 6.9 years followup, the survivorship was 84% with conversion to THR as the end point and with cemented fixation of the acetabulum as the main cause of failure. As with the first experience with cementless metal-on-polyethylene surface arthroplasty,[5] cementless acetabular fixation is reliable and durable without compromising acetabular bone stock. Changes on the femoral neck and around the stem do not differ from those seen in the McMinn components. The neck narrowing most likely reflects a remodeling process not fully understood, which may put the hip at risk of fracture or with time to loosening. The appearance of radiolucencies early in followup is of concern because those greater than 1 mm have been shown to represent implant loosening. However, not all patients are symptomatic and may not require reoperation, and this may be dependent on the quality of the head at the time of implantation and femoral component position, a valgus orientation being more favorable.

The introduction of a metal-on-metal bearing for surface arthroplasty of the hip has permitted the use of a thin acetabular component preserving not only femoral but also acetabular bone stock. These early results with a 97% survivorship at 3 years have shown a significant decrease in short-term failures and equal clinical functional results to THR for this patient age group. The Surface Arthroplasty Risk Index presented may prove useful in the selection of patients for this conservative hip replacement. However, its ultimate validity still needs to be verified during a longer period of followup. The last symposium published on surface arthroplasty of the hip concluded that surface arthroplasty should not be considered a standard arthroplasty and should be done only by surgeons with considerable experience in hip reconstruction.[41] This conclusion still is valid today with the longevity of this implant relying mainly on the femoral side where the bone stock can be compromised by long-standing disease. When this occurs, one can cement the short stem or proceed with a THR based on patient's age and expectation.

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