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Optimizing Patient Selection and Outcomes with Total Hip Resurfacing

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Short-term failures of total hip resurfacing have been related to specific characteristics of the proximal femur. A radiographic arthritic hip grading scale was used to assess four characteristics of the proximal femur: bone density, shape, biomechanics, and focal bone defects. Hips with no unfavorable characteristics were Grade A, hips with one unfavorable characteristic were Grade B, hips with two unfavorable characteristics were Grade C, hips with three unfavorable characteristics were Grade D, and hips with four unfavorable characteristics were Grade F. One hundred forty-seven consecutive hips were treated with metal-on-metal resurfacing by a single surgeon. There were no femoral neck fractures. Of the 91 hips eligible for a minimum 2 year followup, 90% were Grades A or B, 10% were Grade C, and none were Grades D or F. With a minimum 2-year followup, arthritic hip grading was associated with preoperative Harris hip score, occurrence of mild to moderate postoperative pain, preoperative and postoperative range of motion, preoperative and postoperative hip center of rotation, preoperative and postoperative horizontal femoral offset, preoperative and postoperative limb length discrepancy, and acetabular radiolucencies. Hips with a lesser degree of secondary arthritic changes have a higher arthritic hip grade and better outcomes with total hip resurfacing. Relatively strict selection criteria for resurfacing were associated with a low occurrence of short-term failures.

Level of Evidence: Prognostic study, Level II (retrospective study). See the Guidelines for Authors for a complete description of levels of evidence.

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There is an increasing number of total hip resurfacing procedures using a metal-on-metal bearing prosthesis with hybrid fixation (cementless acetabulum and cemented femur).[11] When resurfacing was pursued in the 1970s and 1980s the main indication for the procedure was end-stage arthritis in a young patient. Resurfacing was especially attractive because of the limited durability of total hip arthroplasties (THAs) in young patients and the lesser outcomes of revision THA.[6,8]

Advances in THA include modularity, improved fixation, and more wear resistant bearings with larger diameters that improve the outcomes and longevity of primary and revision THA.[10] Femoral side failures of resurfacing include femoral neck fracture, osteonecrosis, and aseptic loosening, which can result in a 5-year survivorship that is less than modern THA.[2] Preoperative characteristics of the proximal femur, such as low bone density and bone defects larger than 1 cm, can influence the risk of femoral side failure and biomechanical outcomes.[4,12] To avoid short-term complications, stratify results, and improve outcomes, there is a need to refine patient selection criteria for hip resurfacing based on characteristics of the proximal femur.

We therefore analyzed the relationship between selected radiographic characteristics of the arthritic proximal femur and the outcomes after total hip resurfacing.

MATERIALS AND METHODS

At the time of this study, total hip resurfacing implants were considered investigational by the Food and Drug Administration (FDA). The research protocol and informed consent for this study were approved by the hospital investigational review board and conducted under the auspices of the FDA with an Investigational Device Exemption (IDE). From October 17, 2000 to December 20, 2004, 147 hips in 121 patients were implanted with the same metal-on-metal bearing total hip resurfacing system (Conserve Plus®, Wright Medical Technology, Arlington, TN) by the senior author (TPS) using a posterior approach. These 147 procedures were the first done in this series. Seventy-nine of the 121 patients (91 hips) had a minimum 2 years of followup. The 79 patients had a mean age of 48 years [range, 30–67 years; standard deviation (SD), 8.3 years], a mean height of 175.25 cm (range, 155–180.25 cm; SD, 8.6 cm), mean weight of 84.8 kg (range, 51.7–144.7 kg; SD, 18 kg), mean body mass index (BMI) of 27.3 (range, 20.5–44.8; SD, 4.8), and a mean preoperative University of California Los Angeles (UCLA) activity score of 4.3 (range, 2–9; SD, 1.5). Sixty-eight hips (75%) were implanted in 56 men, and 23 hips (25%) were implanted in 23 women. The men were an average of 12.7 cm taller ($p < 0.0001$) and 15 kg heavier ($p = 0.0005$) than the women. The primary diagnosis was osteoarthritis in 87 hips (95%), osteonecrosis in one hip (1%), rheumatoid arthritis in one hip (1%), and ankylosing spondylitis in two hips (2%) in one patient. Fifty-seven hips (63%) were classified as Charnley class A, 29 hips (32%) were classified as Charnley class B, and five hips (5%) were classified as Charnley class C.

Of the 79 patients (91 hips) eligible for 2-year followup, five patients (six hips) were lost to followup. Three patients (three hips) are due for the 2-year followup evaluation. One patient (one hip) was revised to a conventional THA because of femoral loosening 17 months postoperatively. This component was loose radiographically at 12 months. The retrieved specimen showed loosening at the cement–bone interface with little evidence of cement intrusion into bone. Lesser trochanteric suction had not been used. Minimum 2-year followup data were available for 81 hips in 70 patients with a mean followup of 31 months (range, 24–48 months).

All acetabular components were nominally 5 mm thick with sintered, small bead, porous coating for cementless fixation. All femoral components were fixed with bone cement (Simplex P, Stryker, Mahwah, NJ). The first 83 hips (73 patients) were cemented without proximal femoral suction. In the subsequent 64 hips (52 patients), suction was used during femoral cementing through an arthroscopy cannula inserted into the lesser trochanter. The intraosseous negative pressure created by the suction eliminates bleeding from the prepared femoral head and suction was maintained until the cement hardened. All patients were evaluated prospectively using the Harris hip score,[9] the UCLA activity score,[1] and standard radiographs.

In contrast with THA, characteristics of the arthritic femoral head and neck can influence technical aspects of the resurfacing procedure and have been related to the risk of femoral side failure and biomechanical outcomes.[2,4,12] A radiographic grading system was developed to assess the arthritic proximal femur preoperatively. Hips were assessed by the surgeon for four characteristics: bone density, shape, biomechanics, and focal bone defects. Bone density was assessed qualitatively as within normal range or below normal. Suboptimal shape was characterized by a head-neck (diameter) ratio of less than 1.2 cm or a neck length of less than 2 cm. Poor hip biomechanics was defined as a limb-length discrepancy greater than 1 cm or a neck-shaft angle less than 120°. Focal defects of bone of greater than 1 cm in diameter, such as a large degenerative cyst, were noted. Patients' hips with no unfavorable characteristics were Grade A for resurfacing (Fig 1), hips with one unfavorable characteristic were Grade B, hips with two unfavorable characteristics were Grade C (Fig 2), hips with three unfavorable characteristic were Grade D, and hips with four unfavorable characteristics were Grade F.

Fig 1. A preoperative AP radiograph shows a Grade A hip. This hip has obvious loss of articular cartilage, but minimal secondary changes. The shape of the proximal femur, the bone density, and the mechanics are essentially normal. There are no defects in the femoral head.

Biomechanical parameters, including the hip center of rotation, femoral offset, and relative limb length were measured preoperatively and on radiographs taken at the first postoperative followup evaluation using published methods.[12] The femoral components were evaluated for any radiolucencies around the stem and for any change in component position.[2] The presence of radiolucent lines adjacent to the acetabular component were recorded in three zones as described by Charnley[7] on anteroposterior (AP) radiographs obtained at the most recent followup evaluation. Radiographs also were assessed for acetabular component migration or other change in position.

Data were analyzed using Stata™ statistical analysis software (Stata Corporation, College Station, TX). The student's t test, Fisher's exact test, or one-way analysis of variance (ANOVA) was used to compare differences between selected subgroups. A p value ≤ 0.05 was considered significant.

Fig 2. A preoperative AP radiograph shows a Grade C hip. The degeneration of this hip is secondary to Legg-Calve-Perthes disease. Remodeling has resulted in a poorly defined head–neck junction with a broad neck and a relatively varus neck–shaft axis.

RESULTS

Of the 91 resurfaced hips in 79 patients with a minimum 2-year followup, 43 (47%) were Grade A, 39 (43%) were Grade B, nine (10%) were Grade C, and none were Grades D or F. In 10 hips there was low bone density, in 14 hips there was poor shape, in eight hips there was poor mechanics, and in 25 hips there was a focal defect. Of the 39 Grade B hips, there was poor shape in 12 hips (31%), there was low bone density in six hips (15%), there were focal defects in 19 hips (49%), and there were poor mechanics in two hips (5%). Of the nine Grade C hips, there were poor shape and focal defects in one hip (11%), there were poor shape and poor mechanics in one hip (11%), there were low bone density and focal defects in two hips (22%), there were low bone density and poor mechanics in two hips (22%), and there were focal defects and poor mechanics in three hips (33%).

The mean Harris hip score improved ($p < 0.001$) 49.1 points postoperatively to 95.3 (range, 60–100; SD, 6.6), an improvement of 49.1 points. Of the 81 hips with minimum 2-year postoperative data available for study, 38 hips (47%) had no pain at the latest followup, 34 hips (42%) had slight pain, seven hips (9%) had mild pain, and two hips (2%) had moderate pain. No patients reported marked pain.

The mean postoperative UCLA activity score[1] improved ($p < 0.001$) postoperatively a mean of 3.8 points to 8.2 (range, 4–10; SD, 1.5). We found no correlation between the UCLA activity scores and Harris hip scores.

There were no femoral neck fractures in any of the 121 patients (147 hips). The mean preoperative neck-shaft angle was 139° (range, 121–152°; SD, 5.9) and the mean postoperative stem-shaft angle was 144° (range, 128–160°; SD, 5.8). There were no radiolucent lines around any of the femoral components at a minimum of 2 years followup. Radiolucent lines were observed in 33 of the 81 acetabular components. These lines were less than 1 mm thick in 31 components and 1 to 2 mm in two components. Twenty acetabular components demonstrated radiolucent lines limited to only one zone (Zone 1 in 16 components and Zone 3 in four components), 12 had radiolucent lines in two zones (Zones 1 and 2 in one component, and Zones 1 and 3 in 11 components), and one component had radiolucent lines in all three zones.

Hip grade related ($p = 0.004$) with the preoperative but not the postoperative Harris hip score (Table 1). Patients reported some pain during the latest followup in 54% of Grade A hips, 50% of Grade B hips, and 62% of Grade C hips ($p = 0.8$). The presence of mild or moderate pain reported by patients during the latest followup in Grade A hips (1 hip; 3%) was less frequent ($p = 0.03$) than in Grades B and C combined (8 hips; 18%).

Preoperatively, patients with a lower bone density had lower ($p = 0.05$) Harris hip score [41.3 versus 46.9, 95% confidence interval (CI) of the difference: −0.05–11.3]. Patients with poor biomechanics had lower ($p = 0.0002$) Harris hip scores (35.3 versus 47.3, 95% CI: 5.7–17.5). There was no association between poor shape or focal deficiencies and Harris hip scores. Postoperatively, there was no association between any of the components of the arthritic hip grade system and Harris hip scores. Preoperatively, patients with poor bone shape had higher ($p = 0.01$) pain scores (12.1 versus 1.03, 95% CI 0.4–3.1). Postoperatively, there was no association between any of the components of the arthritic hip grade system and pain scores.

Patients with higher-grade hips had better ($p = 0.0004$) mean preoperative flexion (Table 1) whereas patients with lower-grade hips showed more postoperative improvement in range of motion (ROM). When the improvements in ROM in patients with Grade A hips were compared with patients with Grade B and C hips combined, patients with Grade B and C hips had significantly greater improvement in flexion (8.5º, 95% CI: 16º–30º, $p = 0.04$), extension

TABLE 1. Outcomes by Hip Grade

	Grade A*	Grade B*	Grade C*	p-Value between 3 Groups	Grades B & C*	p-Value Between A vs. B+C
Pre-op Harris Hip score	49 (27–63) [8]	45 (29–59) [8]	39 (25–55) [9]	0.004	44 (25–59) [9]	0.01
Mild or moderate post-op. pain (% of hips)	3	19	13	0.07	18	0.03
Pre-op flexion (degrees)	100 (60–120) [17]	84 (35–125) [19]	83 (35–110) [26]	0.0004	84 (35–125) [20]	0.0001
Post-op flexion (degrees)	117 (90–160) [13]	109 (80–150) [16]	114 (85–140) [17]	0.1	110 (80–150) [16]	0.05
Improvement in flexion (degrees)	17 (−20 to 50) [16]	24 (−10 to 75) [20]	32 (10–75) [22]	0.07	26 (−10 to 75) [20]	0.04
Pre-op COR, vertical (mm)	15.2 (1.7–22.5) [4.0]	17.1 (9.5–26.4) [4.4]	18.3 (11.0–27.0) [5.6]	0.0005	17.4 (9.5–27.0) [4.6]	0.05
Post-op COR, vertical (mm)	14.7 (9.3–24.7) [3.5]	16.3 (9.5–24.3) [4.4]	18.6 (11.1–25.8) [4.9]	0.05	16.9 (9.5–25.8) [4.6]	0.04
Pre-op horizontal offset (mm)	36.9 (22.9–50.9) [7.2]	30.1 (21.7–39.2) [5.0]	31.0 (21.5–38.0) [7.0]	0.0005	30.2 (21.5–39.2) [5.5]	0.0001
Post-op horizontal offset (mm)	34.7 (23.8–44.4) [5.8]	30.3 (17.6–50.3) [7.1]	31.8 (19.9–36.0) [5.7]	0.04	30.7 (17.6–50.3) [6.8]	0.01
Pre-op limb length discrepancy (mm)	−3.4 (−13.2 to 6.3) [3.8]	−4.4 (−22.2 to 8.7) [6.6]	−10.9 (−24.8 to 3.3) [9.8]	0.01	−5.9 (−24.8 to 8.7) [7.9]	0.1
Post-op limb length discrepancy (mm)	1.5 (−8.8 to 24.2) [7.2]	−1.7 (−16.8 to 15.1) [7.6]	−10.4 (−25.8 to −2.8) [8.7]	0.001	−3.8 (−25.8 to 15.1) [8.6]	0.01
Radiolucent lines (% of hips)	35	36	88	0.04	45	0.2

*Mean (range) [stan. dev.]

(6º, 95% CI: 1º–12º, p = 0.02), flexion arc (15º, 95% CI: 5º–25º, p = 0.004), abduction (13º, 95% CI: 6º–19º, p = 0.0003), abduction arc (19º, 95% CI: 10º–28º, p = 0.0001), and external rotation (7º, 95% CI: 0º–15º, p = 0.05) than patients with Grade A hips.

Patients with all grades of hips had similar mean postoperative UCLA activity scores. The mean UCLA activity score in patients reporting any pain during the latest followup was similar to that in patients without pain (8.2 versus 8.1, respectively).

The preoperative hip vertical and horizontal centers of rotation (COR) were less (p = 0.0005) in patients with Grade A hips than in patients with Grade B or Grade C hips (Table 1). The postoperative hip vertical COR was also less (p = 0.05) in the patients with Grade A hips compared with patients with Grade B or Grade C hips. The postoperative horizontal offset was greater (p = 0.01) in patients with Grade A hips than in patients with Grade A hips and Grade C hips combined.

The preoperative limb-length discrepancy was greater (p = 0.01) in patients with Grade B and Grade C hips than in patients with Grade A hips (Table 1). Similarly the postoperative limb-length discrepancy was greater (p = 0.001) in the patients with Grade B and Grade C hips than in patients with Grade C hips.

The presence of radiolucent lines was higher (p = 0.04) in patients with Grade C hips (88%) compared with patients with Grade A (35%) or Grade B hips (36%) (Table 1).

DISCUSSION

Total hip resurfacing often has been regarded as an alternative to THA for the treatment of end-stage hip arthritis. The two procedures are distinctly different. Resection and replacement of the femoral head and neck allows the surgeon to modify various mechanical aspects of the proximal femur with THA.[12] Based on our data, outcomes of resurfacing are dependent on preoperative characteristics of the proximal femur: patients higher-grade hips (those with earlier-stage disease) have better outcomes. It is logical that patients whose hips have only a loss of articular cartilage and a relatively normal femoral head and neck would make the best starting material for resurfacing.

The simplicity of this arthritic hip grading system results in some limitations. Bone density is assessed only qualitatively and there is a subjective component in the assessment. The interobserver and intraobserver variability in bone density and arthritic hip grade have not been established. It is not known if arthritic hip grade has any prognostic significance for THA. Additional followup is needed to determine the relationship between hip grade and the long-term survivorship of resurfacing.

The arthritic hip grade is associated with multiple preoperative and postoperative measures including: preoperative Harris hip score, occurrence of mild to moderate postoperative pain, preoperative ROM, postoperative ROM, preoperative and postoperative hip center of rotation, preoperative and postoperative horizontal femoral offset, preoperative and postoperative limb-length discrepancy, and acetabular radiolucencies (Table 1). Arthritic hip grading can identify the more challenging hips preoperatively and has prognostic significance for the outcomes of total hip resurfacing.

The proximal femoral characteristics assessed in hip grading were selected based on theory and practice. The role of low bone density in senile hip fractures is well established. Low bone density would increase the risk of femoral neck fracture following resurfacing.[3] Marginal femoral head osteophytes can change the shape of the proximal femur by progressing in a manner that effectively elongates the head and obscures the femoral head-neck junction, making the neck shorter, broader, and less distinct. Such remodeling reduces the available clearance around the neck and increases the risk of reaming into the neck and weakening it during femoral head preparation. The broadened neck reduces the head-to-neck ratio of the reconstructed hip, which increases the risk of postoperative femoral-acetabular impingement. Varus positioning of the femoral component has been associated with early failure of hip resurfacing.[5] Valgus positioning of the femoral component is preferred, but is somewhat limited by the native neck-shaft angle. The maximum amount of limb length that can be achieved with resurfacing is about 1 cm.[12] Osteoarthritic cysts greater than 1 cm diameter have been associated with early failure of resurfacing.[2,4] Regardless of the etiology, localized bone loss of greater than 1 cm in the proximal femoral head were considered adverse for arthritic hip grading.

This is the senior author's initial series of total hip resurfacing. As with any reconstructive procedure, the outcomes are a function of patient selection. Ninety percent of the hips in this series were Grades A and B, 10% were Grade C, and none were Grades D or F. It is not known how many patients who sought resurfacing were refused because of proximal femoral characteristics that were considered too unfavorable for resurfacing. Using relatively strict inclusion, there have been no femoral neck fractures in the entire series of 147 hips (121 patients). The clinical course and retrieval analysis of the single femoral loosening indicates that the most likely cause of failure was insufficient initial cement penetration.

This arthritic hip grading system considered only characteristics of the proximal femur. There was no assessment of the acetabulum. The vertical hip center of rotation was associated with the arthritic hip grade. The center of rotation was more cephalad in lower grade hips. Although there were few Grade C hips, there was a greater occurrence of acetabular radiolucencies in Grade C hips, which deserves further investigation.

There was a low rate of short-term failures in this initial experience with total hip resurfacing using relatively strict selection criteria. Hips with a lesser degree of secondary arthritic changes have a higher arthritic hip grade and better outcomes with total hip resurfacing.

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