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The Functional Outcome of Hip Resurfacing and Large-head THA Is the Same

A Randomized, Double-blind Study

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Abstract Better functional outcome is believed by some to occur after hip resurfacing (HR) than conventional 28-mm total hip arthroplasty (THA) in young and active patients with hip osteoarthritis. However, the postulated superior outcome of HR over THA may simply be the result of a bias in patient selection or the use of a larger femoral head. We therefore asked whether HR would demonstrate superior functional outcome when compared with a THA with a large-diameter femoral head in a randomized, double-blind study. Gait speed and postural balance evaluations, functional tests, and clinical data were analyzed preoperatively and at 3, 6, and 12 months after surgery. Gait speed was used as the primary outcome measure. Forty-eight patients were randomized in the study and a third group of 14 healthy subjects served as controls. The gait speed and postural balance evaluations, the performance at most functional tests, and clinical scores were similar in HR and large-head THA groups at each followup period. The operated patients reached most control group values at 3 months postoperatively. By these measures, HR did not provide better clinical function over large-head THA.

Level of Evidence: Level I, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Hip resurfacing (HR) has been proposed as the best treatment option to meet the high expectations of the young patient with osteoarthritis with component survivorship of 94% to 99.8% at 5 to 8 years postoperatively [1, 13, 22, 46]. Comparisons of clinical outcome between HR and conventional 28-mm femoral head THA suggest higher activity and quality-of-life scores along with greater range of motion with HR [19, 30, 42, 48]. Short-term gait analysis studies also suggest more symmetric gait pattern, enhanced postural stability, and increased gait speed after HR [21, 37–39]. The reasons for the putative better outcome achieved after HR are unknown, although in addition to the advantages of using a larger diameter femoral head and the more physiological loading of the proximal femur, it may simply be the consequence of a biased selection of more active patients, different postoperative rehabilitation protocol, different restrictions imposed by the surgeon, or the patient's perception about the type of implant. As with HR, large-diameter head THA (LDH THA) with a femoral

Fig. 1 The figure shows an anteroposterior radiograph of the pelvis of a patient (not included in the present study) who has a resurfaced right hip and a large-diameter head metal-on-metal THA on the left hip.

stem also possesses the benefits of large metal-on-metal articulation (Fig. 1). Therefore, comparison of both prostheses would eliminate the femoral head diameter as a possible confounding variable and permit similar postoperative rehabilitation. Moreover, comparison in a double-blind randomized study would eliminate a potential bias of patient selection and any influence of the patient's and evaluator's perception about the type of arthroplasty.

Classic hip scoring systems may not be sensitive enough to demonstrate a difference in clinical outcome of two groups of patients [17]. A more subtle, sensitive, and complementary evaluation of the clinical and functional outcomes after hip arthroplasty can be obtained from evaluations made in a gait and posture laboratory [9, 10, 24, 29, 31]. Subtle differences observed in the gait and posture laboratory may not always be relevant in the aging population but may become clinically important in young or active patients engaging in high-level activities over many years. The walking speed, ability to maintain balance, muscle strength, and a multitude of specific tests have been used extensively in such a setting to analyze the speed and completeness of functional recovery after hip arthroplasty [15, 28, 32, 36–39, 47]. This measure of physical performance is objective, standardized, and assesses different aspects of function, which are not taken into account with clinical scores.

We therefore (1) asked whether patients with HR would have a faster walking speed and better postural balance compared with those with a large-diameter head THA; (2) compared the speed and completeness of gait speed and postural balance recovery of both groups relative to healthy volunteers; and (3) compared the WOMAC, SF-36, Merle D'Aubigné, and UCLA scores, leg length equalization, and femoral offset restoration on radiographs along with the presence of thigh pain and patient perception of their reconstructed hip. We presumed HR would demonstrate a faster gait speed and better function in general, but we expected the difference to be less than that observed between HR and conventional 28-mm THA because of the advantageous use of a larger femoral head diameter in the large-diameter head THA group and the elimination of bias in patient selection.

Materials and Methods

Between February 2006 and April 2007, we invited all 98 patients with hip disease aged younger than 65 years who were candidates for both HR and large-diameter head THA to participate in the study. We excluded patients with Charnley Class B (both hips diseased) or C (polyarticular disease), spinal or lower limb disease other than the degenerated hip that could influence gait and walking performance, neuromuscular disorder, known or suspected metal allergy, and pregnancy. Of the 98 patients screened for enrollment, 43 had at least one exclusion criteria and seven refused to participate, leaving 48 patients for randomization (Fig. 2). A research assistant (DL) randomly allocated these patients to receive either a HR or a large-diameter head THA with the aid of a random number generator using SPSS 15.0 (SPSS Inc, Chicago, IL). A sealed, numerated opaque envelope containing the type of surgery was then assigned to each patient and revealed only to the surgeon the day of surgery. The patients and the evaluators at the gait laboratory were therefore kept blinded with regard to the type of arthroplasty until 1 year after surgery. The research assistant responsible for completeness of data collection was not blinded. The minimum followup was 12 months (mean, 14 months; range, 12–18 months) in both groups. At 12-month followup, three and four patients in the large-diameter head THA and HR groups, respectively, knew the type of implant they received, mainly after having inadvertently seen a radiograph.

The sample size calculation was based on the 0.30-m/s difference in walking speed observed between HR and 28-mm THA as reported by Mont et al. [37]. We assumed the difference in walking speed between HR and large-diameter head THA would be less than the observed difference in the study of Mont et al. [37]. The mean expected difference of walking speed between each study groups at 1 year postsurgery was set at 0.18 m/s. This represented the smallest difference that was associated with a noticeable clinical difference in the patients' perception of exercise performance [43]. With a standard deviation of 0.18 [37], a power of 90%, and a significance level of 5%, the required sample size was 21 patients in each group. Forty-eight patients needed to be recruited to allow for an anticipated 15% loss to followup or withdrawal. In

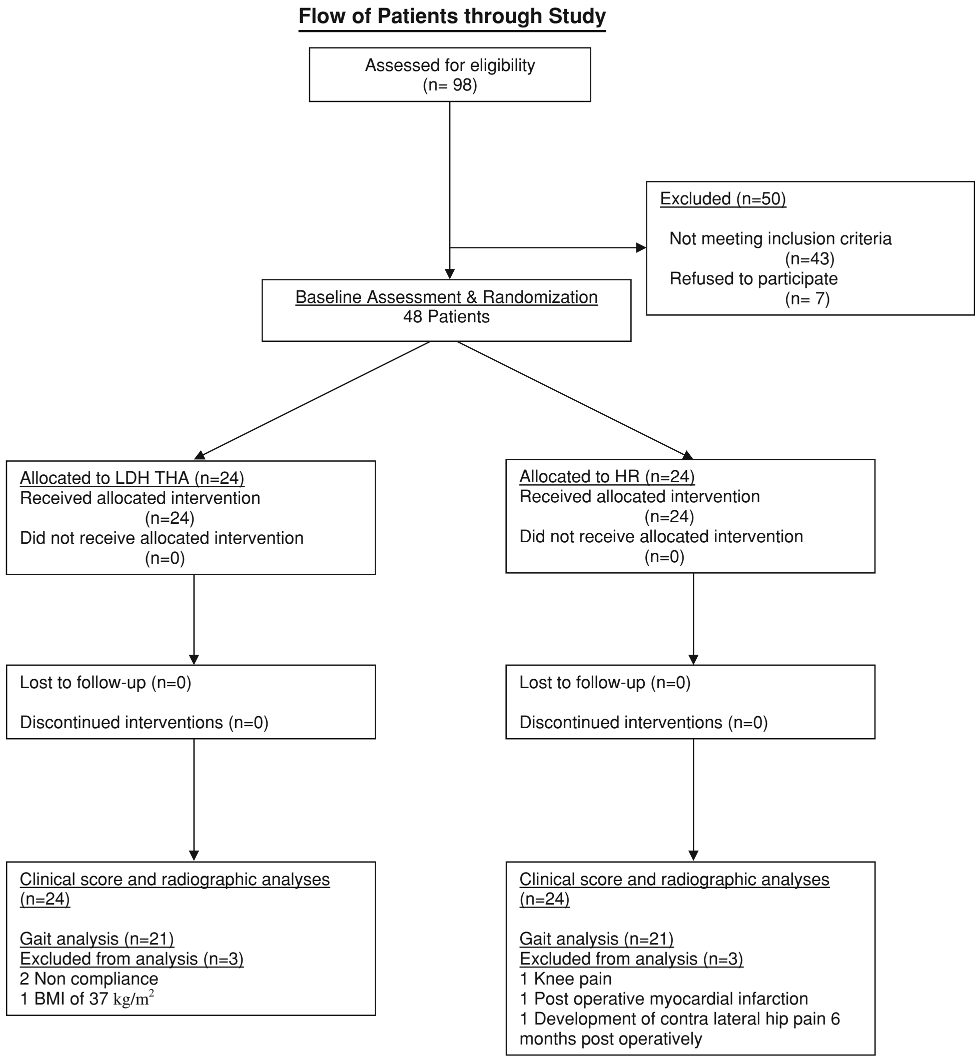

Fig. 2 The figure shows the flow chart of participants throughout the study. LDH THA = large-diameter head THA; HR = hip resurfacing; BMI = body mass index.

addition, 14 volunteers without joint abnormalities or hip problems were selected from the hospital staff to serve as control subjects. All participants gave their written consent and the study received ethical approval from the review boards of all involved institutions.

The demographic data were similar for gender ($p = 0.935$) among the 24 patients forming the HR group (14 males), the 24 patients forming the large-diameter head THA group (15 males), and the 14 control subjects (eight males). The age in the HR group (mean, 49.6 years; range, 38–63 years) was similar ($p = 0.068$) to the large-diameter head THA group (mean, 49.8 years; range, 33–62 years) and control subjects (mean, 44.4 years; range, 31–56 years). The body mass index of the three groups was similar ($p = 0.259$) with an average of 27.9 kg/m^2 (range, 20.2–36.9 kg/m^2), 27.8 kg/m^2 (range, 20.2–35.6 kg/m^2), and 25.8 kg/m^2 (range, 20.8–32.5 kg/m^2), in the HR, large-diameter head THA, and control subjects, respectively. The number of patients diagnosed with osteoarthritis was 18 in the HR group (76%) and 19 in the large-diameter head THA group (80%) ($p = 1.000$). Other diagnoses included mild developmental dysplasia of the hip (two patients in HR and one in LDH THA groups), protrusion acetabuli (one patient in each group), posttraumatic osteoarthritis (one patient in the HR group), avascular necrosis of the femoral head (one patient in HR and two in LDH THA groups), postseptic arthritis (one patient in the LDH THA group), and finally rheumatoid arthritis (one patient in the HR group). All involved hips showed moderate to severe degeneration, whereas the contralateral hip was free of disease. There was no patient with specific anatomy characterized by low femoral offset such as Legg-Calvé-Perthes disease that could influence the femoral offset.

All patients received regional or general anesthesia and were positioned in the lateral decubitus position. We did not plan to give the patient sedation to avoid potential guessing on the type of implants selected, but the operating room staff was made aware of not disclosing any information to the patients or having any discussion about the type of implants used during surgery. Three surgeons (ML, PAV, AR) performed the surgeries through a posterior surgical approach in both groups. All three surgeons had considerable experience with the HR and large-diameter head THA systems used in this study. The fascia lata was opened and the gluteus maximus was split in line with its muscle fibers. The short external rotators were released from the greater trochanter. A posterior capsulotomy was performed and the hip dislocated. For the THA, the standard techniques proposed by the manufacturer for insertion of the CLS femoral stem (Zimmer, Warsaw, IN) were followed. Neck sleeve adapters and three different prosthetic neck-shaft angles (125°, 135°, and 145°) were available to adjust leg length and femoral offset with the large-diameter head THA system. In the HR group, the capsulotomy was completed circumferentially, and the gluteus maximus tendinous insertion on the femur was released in all men, but only when needed in women, to improve femur mobilization. Furthermore, the gluteus minimus was elevated from the ilium. Then, proper femur mobilization allowed preparation and cementation of the corresponding Durom femoral component. For both groups, the Durom acetabular cup ("worldwide" version, not FDA-approved) was inserted as proposed by the manufacturer [50]. This cup is slightly different from the US version of the Durom cup because the coating thickness ranges from 200 to 400 μm compared with 300 to 500 μm for the US cup. Posterior capsulotomy and released short rotators of both groups were repaired with transosseous sutures. A second-generation cephalosporin was given for 24 hours postoperatively and subcutaneous low-molecular-weight heparin was given for 28 days.

Postoperatively, weightbearing as tolerated was allowed in both groups with a daily supervised stretching and strengthening program while hospitalized followed by an outpatient unsupervised strengthening and stretching program for 6 weeks. No specific restrictions with regard to range of motion and muscle stretching and strengthening were applied to any group. High-impact activities were restricted in both groups for 3 months postoperatively.

Gait speed, postural balance, and most of the functional assessments were performed preoperatively and at all followup evaluations (3, 6, and minimum 12 months) in a dedicated gait laboratory. The gait assessments consisted of five walking trials at normal and fast speeds on a 10-m walkway. The normal speed was set at the subject's usual self-selected comfortable speed. The fast walking speed was the maximum speed at which the patient could walk safely without running. Sixteen reflecting markers placed on the specific anatomic landmarks on the lower limbs were captured at 60 Hz with an eight-camera Vicon system (Oxford Metrics Limited, Oxford, UK) and the data were processed with the Vicon Workstation and Polygon software to define gait cycle events used to analyze the spatiotemporal parameters (walking speed, cadence, and step length).

We assessed postural control during a quiet standing task [38]. Subjects were asked to stand as still as possible with feet at shoulder width for 120 seconds on the force platforms. Two embedded AMTI force platforms (Advanced Mechanical Technology Inc, Watertown, MA) recorded at 120 Hz the ground reaction forces and moments. The patients were asked to fix a target located 3 m in front of them at eye level. The center of pressure (COP) trajectory was calculated from the force plate signals. Because the COP represents the outcome of the inertial forces of the body and restoring equilibrium forces of the postural control system, the COP is considered the main biomechanical variable to assess postural control [16, 51]. The total sway-path length (TPL) traveled by the COP was calculated with a lesser TPL reflecting less body sway and thus better quiet standing postural performance [4]. This test was performed twice and the average of both trials is reported.

Specific functional tests measuring physical performance were also performed at the gait laboratory and included the functional reach, the timed up and go, the hip flexor and abductor muscle strength, and the step and hop tests. During the functional reach test, the patient was standing still, one shoulder flexed at 90° and the other arm on the side. We asked the patient to reach as far as possible ahead of him with his index finger without lifting the heels from the ground and the maximum distance reached (in centimeters) was measured with a ruler. The average distance of two trials is reported. This test evaluated postural stability, a higher measured distance reflecting better dynamic postural balance [14, 44]. For the timed up and go test, the patient had to rise from a standard arm chair, walk as fast as possible until he reached a stool placed 10 feet ahead of him, contour it, and come back to the chair and sit back. We recorded the time needed to accomplish this task with shorter time reflecting better physical mobility and speed [41]. The average of two trials is reported. The hip flexor and abductor muscles strength on both sides was assessed using a Penny and Giles handheld myometer (Penny and Giles, Christchurch, UK). This test was repeated twice with a resting period of 1 minute [11, 23]. To limit the interexaminer variability, the peak force generated in Newtons by the hip flexor and abductor muscles of the operated limb was expressed as the percentage of the peak force generated by the sound limb. For the control group, the weaker limb was expressed relative to the stronger limb.

The step test consisted of five consecutive rises and descents from an 18-inch step (using the operated leg to climb up and keeping the same leg on the step when going down) that were performed as fast as possible. We recorded the time to accomplish this task. For the hop test, the patient was asked to hop on one leg as many times as possible for 10 seconds. The minimal requirement was for the patient's toes to leave the ground. The step and hop tests were performed twice. A shorter time at the step test and a greater number of hops at the hop test would represent a better functional recovery. Because of the challenging nature of those tests, they were performed at the gait laboratory only at 12 months followup.

Preoperatively and at all followup evaluations performed at the hospital, the patients completed the WOMAC [7], SF-36 [33], and Merle d'Aubigné [35] questionnaires. At minimum 1 year postoperatively, the UCLA activity score was also completed [6]. Low score on the WOMAC scale and high score on the SF-36, Merle d'Aubigné, and UCLA activity scores indicate better outcome. Finally, we asked the patients about their perception concerning the replaced hip (feels like the natural contralateral hip, feels like an artificial hip but without limitation or with minimal limitations or with substantial limitations), and on the presence of thigh pain at last followup.

Standardized 1-year postoperative radiographs were analyzed by a single evaluator (MG) who was blinded to the functional outcome but could not be blinded to the type of prosthesis. Anteroposterior radiographs of the pelvis were taken with the legs positioned in 15° of internal rotation. The radiographs were scanned (VIDAR VXR-12, Herndon, VA) and analyzed using the Imagika software (Clinical Measurement Corporation, Ridgewood, NJ) as previously reported [19, 20]. The femoral offset and leg length inequality were measured in millimeters by comparing the replaced with the normal contralateral hip. We considered reconstruction of leg length and femoral offset within ± 4 mm of the healthy joint to be optimal [19]. The femoral offset was defined as the perpendicular distance from the center of rotation of the hip to the femoral shaft line. We evaluated the limb length inequality by the perpendicular distance from the teardrop to the lesser trochanter line. Signs of acetabular and femoral implant loosening were assessed at last followup according to Amstutz et al. [2].

All 48 enrolled patients completed the clinical scores and radiographic analysis, whereas 42 of the 48 (88%) enrolled patients were included in the gait analysis, postural balance evaluations, and functional tests (Fig. 2). Three patients undergoing large-diameter head THA could not complete the gait analyses: two because of noncompliance with the protocol and one as a result of difficult positioning of the reflective markers (body mass index of 37 kg/m^2). Three patients in the HR group did not complete the gait analyses as a result of knee pain, postoperative myocardial infarction, and development of contralateral hip pain 6 months postoperatively. Preoperative gait analysis, postural balance evaluations, and specific functional tests were performed in 12 HRs and eight large-diameter head THAs; the remaining patients were not able to perform all the tests as a result of pain or fear of falling. Six patients undergoing HR and three patients undergoing large-diameter head THA did not perform the 3-month evaluation as a result of discomfort in the hip area. All patients but one in the HR group performed the 6-month evaluation. All patients in both groups undertook the minimum 1-year evaluation.

We determined differences between the groups by the chi square test for categorical variables (gender, diagnosis, thigh pain, operated hip joint perception, femoral offset difference, and leg length inequality [in %]) or independent t-test for continuous variables (absolute femoral offset difference and leg length inequality, WOMAC, SF-36, Merle d'Aubigné, and UCLA activity scores) or one-way analysis of variance (ANOVA) (age and body mass index). Because some subjects were unable to perform the preoperative and 3-month gait evaluations, these periods were analyzed separately by means of ANOVA, whereas the 6- and 12-month evaluations were analyzed using a repeated-measure ANOVA (three groups * two evaluations), except for the step and hop tests, which were evaluated only at 12 months and consequently analyzed by one-way ANOVA. If necessary, we analyzed the results with the Tukey post hoc test and paired t-test. Two-sided significance tests were used throughout the analysis. In case of nonnormally distributed data (total path length of the COP, step and hop test), statistical analysis was done after logarithmic transformation [12]. All analyses were performed using SPSS 15.0 (SPSS Inc, Chicago, IL).

Results

During normal and fast walking and for postural evaluations, both study groups showed similar postoperative results. Although the HR group walked faster ($p = 0.036$) than the large-diameter head THA group preoperatively during the normal walking test as a result of a longer ($p = 0.038$) step length, these two parameters became similar at all postoperative evaluations (Table 1). The increased cadence adopted by both study groups at 6 and 12 months resulted in a greater ($p = 0.001$ for large-diameter head THA and $p = 0.008$ for HR) normal walking speed compared with the control group only at the 12-month evaluation. No difference was found preoperatively and at all followups among HR, large-diameter head THA, and control subjects during the quiet standing test as shown by similar total path length of the COP in all groups. There were no differences between the prostheses groups for the timed up and go test, hop test, hip flexor and

Table 1. Results of the gait analysis and postural balance evaluations*

Gait and postural parameters	Results at different followup periods for each study group and the control subjects								
	Preoperatively		3 months		6 months		12 months		Control subjects (N = 14)
	HR (N = 12)	LDH THA (N = 8)	HR (N = 15)	LDH THA (N = 18)	HR (N = 20)	LDH THA (N = 21)	HR (N = 21)	LDH THA (N = 21)	
Normal walking									
Speed (m/sec)	1.19† (0.29)	1.03†,‡ (0.20)	1.16‡ (0.19)	1.24 (0.17)	1.31 (0.18)	1.36 (0.20)	1.44‡ (0.19)	1.46‡ (0.18)	1.29 (0.14)
Step length (m)	0.64†,‡ (0.08)	0.58†,‡ (0.06)	0.61‡ (0.06)	0.64‡ (0.06)	0.65 (0.07)	0.67 (0.07)	0.68 (0.07)	0.69 (0.06)	0.69 (0.08)
Cadence (steps/min)	110.1 (16.2)	106.8 (11.5)	113.9 (10.1)	115.8 (9.3)	120.5‡ (7.0)	121.7‡ (9.0)	125.6‡ (7.5)	126.2‡ (8.7)	112.1 (6.8)
Fast walking									
Speed (m/sec)	1.58 (0.29)	1.50‡ (0.22)	1.62 (0.23)	1.65 (0.15)	1.71 (0.24)	1.68 (0.20)	1.82 (0.24)	1.73 (0.18)	1.71 (0.10)
Postural balance									
TPL of the COP (cm)	113.8 (32.9)	124.8 (20.7)	103.3 (15.3)	117.2 (26.0)	114.4 (26.1)	114.7 (24.2)	108.1 (20.8)	112.3 (24.0)	110.5 (18.4)

* The values are given as the mean (standard deviation); †significant difference between prostheses groups ($p < 0.05$); ‡significant difference for prosthesis versus controls ($p < 0.05$); HR = hip resurfacing; LDH THA = large-diameter head THA; TPL = total path length; COP = center of pressure.

abductor strength ratio. We found differences between the two prostheses groups for only two tests: the functional reach and the step test at the advantage of patients undergoing HR and those undergoing large-diameter head THA, respectively (Table 2). The HR group performed better during the functional reach test at 3 ($p = 0.027$), 6 ($p = 0.019$), and 12 months ($p = 0.001$) postoperatively compared with the large-diameter head THA group. They reached, on average, 4.6 cm farther than the large-diameter head THA group at 12 months postoperatively. The large-diameter head THA group had not been able to reach control subjects' values for the functional reach test at any followup evaluations. As for the step test, the large-diameter head THA group was able to complete the task approximately 3 seconds faster than the HR group ($p = 0.001$). The timed up and go test is the only functional test in which the control group surpassed the prostheses groups with a faster time at all evaluations compared with both study groups ($p < 0.01$ at all followups). At 12 months postoperatively, the control subjects still completed the timed up and go test on average 0.75 to 1 second faster than both study groups (Table 2).

The time period needed for both groups of patients to reach the normal control subject's value for each functional test was 3 months (Table 1), except for the normal walking speed and step length of the HR group, which reached the control value at 6 months postoperatively.

The WOMAC, SF-36, and Merle d'Aubigné scores were similar in both study groups at all evaluations ($p > 0.05$) (Table 3). At 1 year postoperatively, both groups showed similar UCLA activity score ($p > 0.05$). No patient in either group reported thigh pain and no difference was found between the groups regarding the perception of the reconstructed hip ($p > 0.05$) (Table 4). The femoral offset reconstruction and leg length equalization were similar ($p > 0.05$) in both groups (Table 5). No signs of acetabular or femoral component loosening were observed. The surgical complications included three femoral calcar cracks occurring during the insertion of the femoral stem in the large-diameter head THA group that were treated with cerclage wiring. A damaged branch of the obturator artery was ligated and a patient sustained a myocardial infarction in the HR group.

Discussion

Some studies have reported excellent clinical outcome after HR [1, 13]. Furthermore, some comparative studies have reported a better outcome after HR compared with 28-mm THA [30, 42, 48], perhaps because of the use of a more anatomic femoral head and the preferential selection of more active patients in HR. With its large head size, large-

Table 2. Functional tests results*

Functional parameters	Results at different followup periods for each study group and the control subjects								
	Preoperatively		3 months		6 months		12 months		Control subject (N = 14)
	HR (N = 12)	LDH THA (N = 8)	HR (N = 15)	LDH THA (N = 18)	HR (N = 20)	LDH THA (N = 21)	HR (N = 21)	LDH THA (N = 21)	
FR (cm)	37.2 (5.2)	$36.1^{‡}$ (3.9)	$38.7^{†}$ (5.4)	$35.7^{†,‡}$ (5.2)	$37.7^{†}$ (5.5)	$34.5^{†,‡}$ (4.1)	$39.2^{†}$ (5.8)	$34.6^{†,‡}$ (4.3)	39.8 (4.8)
TUG (seconds)	$7.60^{‡}$ (1.70)	$8.00^{‡}$ (1.04)	$7.73^{‡}$ (1.15)	$7.50^{‡}$ (1.03)	$7.07^{‡}$ (0.95)	$7.35^{‡}$ (0.98)	$6.73^{‡}$ (1.00)	$7.07^{‡}$ (0.78)	6.06 (0.87)
Step (seconds)	—	—	—	—	—	—	$18.12^{†}$ (3.57)	$15.00^{†,‡}$ (3.10)	16.92 (3.26)
Hip flexor strength ratio (%)	$77.0^{‡}$ (16.4)	81.3 (27.6)	87.8 (13.9)	84.2 (16.5)	92.1 (14.5)	90.2 (13.5)	91.5 (15.3)	92.1 (7.5)	95.1 (4.1)
Abductor strength ratio (%)	82.7 (22.1)	82.1 (17.4)	85.0 (10.4)	86.1 (17.3)	89.1 (14.4)	89.5 (16.5)	92.6 (9.9)	89.4 (16.2)	87.6 (7.6)
Hop on one leg (number of hops)	—	—	—	—	—	—	20.7 (3.3)	21.2 (3.3)	21.8 (3.2)

* The values are given as the mean (standard deviation); †significant difference between prostheses groups ($p < 0.05$); ‡significant difference for prosthesis versus controls ($p < 0.05$); HR = hip resurfacing; LDH THA = large-diameter head THA; FR = functional reach; TUG = timed up and go.

diameter head THA could challenge the clinical superiority of HR. We asked whether HR could, in a randomized, double-blind clinical study, maintain its superior clinical outcome compared with large-diameter head THA in terms of gait speed, postural balance, and performance on several functional tests. A control group served to evaluate the completeness and speed of recovery. We also compared clinical score and radiographic analysis. We hypothesized that patients with HR would walk faster than those with large-diameter head THA, but the difference would be of less magnitude than the one observed between HR and 28-mm THA.

This study has some limitations. The walking speed was chosen as our primary outcome because it represents an important component of lower extremity function and because walking ability is included in most clinical hip scoring systems. Walking speed is a well-accepted, objective, reliable, valid, and reproducible measure [5] that has been used extensively to study the functional outcome after 28-mm THA [28, 36, 37, 39, 40, 49]. We based our sample size calculation and power analysis on a difference of 0.18 m/s in gait speed. For a 6-minute walk at a slower corresponding gait speed, the distance walked would be shorter by 64.9 meters, or 212 feet. The smallest difference in the 6-minute walking distance test that was associated with a noticeable clinical difference in the patients' perception of exercise performance was a mean of 54 m, or 177 feet. It is possible that more demanding, validated clinical tests or a more detailed evaluation of gait kinematics could show a clinical difference between HR and large-diameter head THA. However, in light of the inability of this study to demonstrate a clear difference in outcome despite the multiple tasks performed, such a difference would undoubtedly be of little clinical importance. The physical tasks performed by our patients were developed and validated to measure physical performance in elderly patients. We have added more demanding tasks (hop and step test) to improve our ability to find functional differences between HR and large-diameter head THA, although these tasks have never been validated. This study underlies the need to develop more discriminating measures of clinical function because the most commonly used tools measuring the outcome of hip arthroplasty are clinical hip scores, which are not sensitive enough to discriminate the outcome between a young and active groups of patients as a result of a ceiling effect [17, 18]. Other limitations of our study include the difficulty in fully monitoring the preoperative functional status and the early rehabilitation process because of the inability of some patients to complete the preoperative and 3-month evaluations. The small preoperative sample size may explain the difference in preoperative walking speed observed between the groups. The blinding process of patients was not achieved perfectly

Table 3. Functional and clinical scores

Functional and clinical tests	Results at different followup periods for each study group							
	Preoperatively		3 months		6 months		12 months	
	HR (N = 24)	LDH THA (N = 24)	HR (N = 24)	LDH THA (N = 24)	HR (N = 24)	LDH THA (N = 24)	HR (N = 24)	LDH THA (N = 24)
WOMAC*	46.5 (14.9)	54.3 (14.5)	15.2 (9.9)	11.9 (16.1)	7.0 (10.9)	5.5 (15.0)	3.0 (8.4)	2.7 (8.5)
	26–79	30–80	3–39	0–36	1–42	0–29	0–12	0–16
SF-36: Mental*	34.3 (8.1)	35.1 (7.2)	37.5 (11.5)	41.2 (10.0)	45.1 (14.5)	54.3 (13.7)	51.9 (7.2)	52.1 (10.9)
	17–52	18–45	27–50	30–58	21–57	48–62	45–60	36–65
Physical*	47.7 (10.1)	46.8 (12.1)	54.3 (11.4)	53.4 (9.2)	54.3 (5.2)	57.6 (2.7)	55.2 (5.1)	53.3 (8.7)
	30–64	27–68	40–59	39–65	46–62	49–63	48–62	53–70
MA*	11.0 (2.8)	10.5 (2.3)	17.0 (1.1)	17.4 (1.0)	17.5 (1.0)	17.9 (1.1)	17.9 (0.4)	18.0 (0.0)
	7–16	5–16	14–18	16–18	14–18	16–18	16–18	18
UCLA activity*	—	—	—	—	—	—	8.0 (1.5)	8.3 (1.7)
							5–10	6–10

* The values are given as the mean (standard deviation), range; HR = hip resurfacing; LDH THA = large-diameter head THA; MA = Merle D'Aubigné; UCLA = University of California, Los Angeles.

Table 4. Patient perception of their reconstructed hip and the presence of thigh pain*

Category of perception	Study groups		p value (adjusted)
	HR (N = 24)	LDH THA (N = 24)	
Perception about the replaced hip			
Natural hip	15 (62%)	14 (58%)	0.775
Artificial hip without limitation	5 (21%)	7 (29%)	
Artificial hip, minimal limitation	4 (17%)	3 (13%)	
Artificial hip with significant limitations	0 (0%)	0 (0%)	
Presence of thigh pain	0 (0%)	0 (0%)	1.000

* The values are given as the number of patients with the percentage in parentheses; HR = hip resurfacing; LDH THA = large-diameter head THA.

Table 5. Radiographic analysis at 1-year followup

Radiographic parameters	Study groups		p value (adjusted)
	HR (N = 24)	LDH THA (N = 24)	
Femoral offset difference (mm)*	−3.3 (4.8)	0.9 (6.3)	0.013
	−12.5 to 7.0	−11.6 to 10.9	
Number and percent of patients with femoral offset within ± 4 mm†	14 (58%)	9 (38%)	0.248
Leg length inequality (mm)*	−0.4 (2.8)	−0.1 (4.3)	0.782
	−5.8 to 4.8	−9.2 to 6.4	
Number and percent of patients with leg length inequality within ± 4 mm†	21 (88%)	17 (71%)	0.286

* The values are given as the mean (standard deviation), range; †the values are given as the total number of patients within ± 4 mm with the percentage in parentheses; HR = hip resurfacing; LDH THA = large-diameter head THA.

(35 of 42 [83.3%]) and this may have affected the performance of the patients during the functional evaluations, although we believe this should have been to the advantage of the HR group, which did not perform better in this study. We evaluated the control group only once instead of four times like with our study groups. The familiarity of the

study groups with the different tasks may have been advantageous at the 12-month evaluation and thus could explain the better performance of the large-diameter head THA groups on the step test compared with control subjects. Finally, the followup of this study is short and there is a potential to see differences in the study groups with longer followup.

Our data failed to demonstrate a clear difference in gait speed between HR and large-diameter head THA up to 1 year after surgery. We believe the design and power of this study can support this affirmation and that our observations are generalizable. This is the only study, to our knowledge, that compares the outcome of these two procedures. Few studies have compared gait and postural characteristics between HR and 28-mm THA. In a study by Mont et al. [37] comparing gait speed between these two groups, the HR group walked on average 0.30 m/sec faster than 28-mm THA. Nantel et al. [38] showed better postural balance during the quiet standing test in HR compared with 28-mm THA. Gore et al. [21] demonstrated greater walking velocity and muscle strength after HR compared with conventional 28-mm THA. Some authors presumed better stability, optimal biomechanical reconstruction, and physiological loading of the proximal femur in HR might explain the differences with 28-mm THA. In HR, conservation of proximal femoral bone stock facilitates restoration of normal hip biomechanics [19], may provide a more physiological loading of the femur, which potentially improves function [25], and may eliminate the development of thigh pain. Those postulated advantages of HR were challenged by this study. Indeed, the use of a large femoral head in large-diameter head THA improved the precision of our biomechanical reconstruction of the hip compared with conventional 28-mm THA because the surgeons did not have a tendency to increase leg length or femoral offset to compensate for the occasional unsatisfactory stability obtained with a 28-mm articulation diameter [19]. The more physiological loading of the femur in HR did not provide a functional advantage as shown by our multiple measures of function and no patient had thigh pain as a result of the presence of a femoral stem in the large-diameter head THA group. Among all clinical evaluations executed by the patients of this study, only one test showed a difference in favor of HR: the functional reach test. At 12 months, the HR group was able to reach an average of 4.6 cm farther than the large-diameter head THA group. Better balance and proprioception in HR resulting from conservation of the proximal femur may explain this difference, although this hypothesis would be stronger if better performance of the HR group was achieved during the quiet standing test and a more frequent perception that the replaced hip feels like a normal hip had been observed. On the other hand, the large-diameter head THA group performed better on the step test. Although reattached during closure, the release of the gluteus maximus tendon in most patients with HR may have produced a deficit in gluteus maximus muscle function, which is solicited during stairclimbing. The timed up and go test is the only functional test in which the control group surpassed the prostheses groups at all followups. One explanation could be the extremely high axial and rotational loads on the hip generated by the action of standing from a sitting position [8, 26, 27].

Many studies assessing recovery after conventional 28-mm THA demonstrate functional deficits such as reduced range of motion, muscle weakness, decreased gait speed, and lower hip extensor and abductor moments persist well beyond 1 year after surgery [15, 28, 32, 36, 40, 47]. In this study, both groups demonstrated much quicker recovery with normalized performance at most gait and postural tests observed at the 3- to 6-month evaluations. This is likely the consequence of the young age and motivation of our patients, but may also result from the use of more performing implants. The only persistent functional difference of both study groups compared with control subjects was observed during the timed up and go test. This is rather surprising because the fast walking speed is similar in all groups from the 3-month evaluation. The operated patients may have had more difficulties in rising quickly from the chair, making the 180° turn at fast speed, or sitting on the chair. Extremely high axial and rotational loads on the hip are generated by this action [8, 26, 27].

As anticipated, the WOMAC, SF-36, Merle-D'Aubigné, and UCLA scores were not significantly different between the groups of this study. There was no specific technical complication or revision in both techniques. Because we could not demonstrate a clinical benefit of HR over LDH THA in this study, the only remaining clear advantage of HR would seemingly be proximal femoral bone conservation facilitating revision surgery [3]. However, because more studies now show the uncemented and cemented femoral stem in THA can be longlasting treatment options [34, 45], survivorship of the femoral HR component should demonstrate comparable survivorship before proximal bone conservation can be considered a true advantage.

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