Confronting hip resurfacing and big femoral head replacement gait analysis

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Abstract

Improved hip kinematics and bone preservation have been reported after resurfacing total hip replacement (THRS). On the other hand, hip kinematics with standard total hip replacement (THR) is optimized with large diameter femoral heads (BFH-THR). The purpose of this study is to evaluate the functional outcomes of THRS and BFH-THR and correlate these results to bone preservation or the large femoral heads. Thirty-one patients were included in the study. Gait speed, postural balance, proprioception and overall performance. Our results demonstrated a non-statistically significant improvement in gait, postural balance and proprioception in the THRS confronting to BFH-THR group. THRS provide identical outcomes to traditional BFH-THR. The THRS choice as bone preserving procedure in younger patients is still to be evaluated.

Introduction

Total hip replacement (THR) represents the gold standard for the treatment of symptomatic hip arthritis. The available standard THR devices, possessing a wide variety of implants with advanced tribologic technologies (metal on polyethylene, ceramic on ceramic, metal on metal), lead to excellent long-term results and significantly improve elder's population quality of life. Concern however exists about optimal THR outcomes in the younger and more active population.[1] Total hip resurfacing replacement (THRS) represents an alternative technique that involves capping the femoral head and preserving the bone of proximal femur. Best candidates for resurfacing are patients younger than 60 years with good bone stock. Although the surgical approach is similar to a standard THR, it retains most of the femoral head and is thought to preserve proprioception.[2] Literature data on THRS demonstrate that the use of large diameter femoral heads results in a more physiological loading of the proximal femur and improves clinical outcome.[3] Similarly, big femoral head THR (BFH-THR) restores normal hip biomechanics and possesses the benefits of decreased risk of dislocation and increased range of motion. On the other hand, for younger patients, a conserving bone procedure may offer not only better balance and proprioception but also a good bone stock for a future revision.[2-5]

Classic hip scoring systems may fail to demonstrate differences between these prostheses. A more subtle, sensitive, and complementary evaluation of their clinical and functional outcomes can be obtained through gait and posture analysis.[6,7] These systems provide an easy, reproducible and objective method for quantifying gait changes after THR.[8,9] Objective gait analysis outcomes have been positively correlated with patient's subjective changes in the quality of life after THR, as determined on the WOMAC and SF36 scores.[6,10] Thus subtle differences may become clinically important in young or active patients engaging in high-level activities. The walking speeds, the ability to maintain balance and a multitude of specific tests have been used extensively to analyze functional recovery after hip arthroplasty. The measurements on physical performance are objective, standardized and assess different aspects of function. It has been concluded that preoperative gait adaptations persisted 1 year postoperatively in patients with THR.[11-16] Gait characteristics of THR, evaluated 1 to 2 years post surgery, predict biomechanical characteristics of the hip over a lifetime.[17,18]

Since conservation of bone stock is crucial for younger, active patients who may require future revisions, further assessment of functional efficacy of THRS devices *in vivo* is required to properly compare their outcomes with biomechanically similar BFH-THR. We performed a randomized study comparing these two prostheses. We presumed that the advantageous use of a large femoral head diameter in both groups (THRS and BFH-THR) would demonstrate a more physiological gait, better function and eliminate femoral head diameter as a possible confounding variable. Moreover, it could eliminate the potential bias of patient selection as well as any influence of the patient and evaluator's perception about the implant type.

Materials and Methods

Between October 2008 and June 2011, 48 patients were enrolled in this study after obtaining institutional Review Board (IRB)/Ethics Committee approval. Patients with preexisting osteoarthritis of the contralateral hip or pathologies affecting gait analysis (neuromuscular disorders) were excluded. Forty-one patients met the inclusion criteria and were randomly distributed to the THRS and BFH-THR study groups. The personnel of the gait analysis lab had no information on patients' distribution and implant selection.

All patients were operated by the same surgeon. The BFH-THR study group consisted of 21 patients (Wright-BFH, Profemur) while the THRS group of 20 patients (Wright, Conserve Plus). Since gait analysis studies report that superior functional results for THRS can be obtained through a posterior approach, even with minimal invasive techniques, a Moore's approach was selected for all patients of this study.[19-23] The postoperative rehabilitation program was similar for both groups. High-level activities were forbidden for a period of 3 months. All patients were submitted to thorough clinical and radiological evaluation preoperatively, postoperatively and at regular follow-ups at the 1st, 7th, 12th and 24th month.

Clinical assessment included functional and subjective hip scores as well as gait analysis. Patients were instructed to complete Harris Hip Score, SF36, Womac and Visual Analogue Scale for pain preoperatively and at the one-year and second-year follow-up. Additionally, they were asked to perform the timed *Up&Go* test. This is a reliable and valid method for

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quantifying functional outcomes. The test is quick, requires no special equipment or training, and is easily included as part of the routine medical examination.[24] Gait analysis, postural balance at one (dynamic) and both standing legs (static), proprioception at one and both standing legs and performance as Romberg quotient results was analyzed. Stabilo pro system® by Protec® was used for estimation of gait analysis. The system is composed of three basic instruments: i) a 48×48 cm basic barometric platform, the Basic Plana, with 2304 sensors for the static and dynamic analysis of the limp, ii) the Stabilometry and Linea plana, a 1.92 cm long pressure platform with 9216 sensors that allows control of all gait characteristics as well as evaluation of the gravity center for the whole body and of each limp separately and iii) the Fly, a dynamic inclination platform used for the study of proprioception, balance and neuromuscular synchronization. No patient was lost during the follow-up period.

The resulting parameters that have been estimated and have been under statistical analysis were: velocity of walk (cm/sec), time of walk (sec), length of step (cm), length of swing phase (cm), degrees of abduction (°) and the corresponding quotient of the operated and physiological leg. Also the maximum pressure (KPa[r]) and mean pressure of the operated leg (KPa[r]), percentage of pressure and surface of pressure (cmq) of the operated leg and the corresponding quotient of the operated and physiological leg. During the static (two legs standing) and dynamic (one leg standing) balancing control have been estimated the center of balance, the center of weight and their deviation's (mm), the maximum pressure (KPa[r]) and the mean pressure of both legs (KPa[r]), the percentage of pressure and percentage of surface (cmq) of both legs. The corresponding quotients of the operated and physiological leg were calculated. During the proprioception control were evaluated the centers of pressure and their deviations (mm), the overall velocity (mm/sec), the ecliptic area designed (mmq), the (VFY) velocity/displacement, the (LSF) distance/surface and the area from the center of weight (mm). The Romberg quotients were calculated.

Statistical analysis showed that a sample size of 16 evaluable patients per group was requires to achieve an 80% probability of demonstrating a between group difference of >20 (DS>20) in elliptic surface with a significance of <5% (two tailed test). The quantitative and qualitative variables are represented by the number of patients (N), mean value (mean), median, standard deviation (SD), IQR and the frequencies (n) and percentages (%) respectively. Comparisons of absolute values of all variables between groups were performed using the independent samples t-test or the Welch test (in case of unequal variances). Comparisons of variables during the observation period (preoperative *vs* postoperative) were performed using paired samples t-test. To indicate the trend from preoperative to postoperative of treatments, the median percentage changes was calculated. Comparison of percentage change from preoperative to postoperative between the 2 groups was analyzed using the Mann-Whitney test. Statistical analyses of qualitative variables were performed using Fisher's exact test. All tests were two-sided, statistical significance was set at P<0.05 .All analyses were carried out using the statistical package SPSS vr 17.00 (Statistical Package for the Social Sciences, SPSS Inc., Chicago-Ill., USA).

Results

Pathologic modalities for both study groups included osteoarthritis, avascular necrosis and developmental disease of the hip and posttraumatic arthritis. Demographic data were similar for both groups (Table 1). The mean age for THRS and BFH-THR groups was 54.9 years (range 45-63 years) and 57.1 years (range 49-65 years), respectively. Both groups displayed a similar body mass index. No statistically significant difference was detected between the two groups regarding height, weight, age and femoral head diameter (52 mm, range 49-56 mm). The male/female ratio in THRS group was 11/3 and in the BFH-THR group 12/5 (Figure 1).

Gait analysis for all hips included normal (mean SD THRs 1446 m/sec *vs* BFH-THA 1344 m/sec) and fast walking (mean SD THRS 1798 m/sec *vs* BFH-THR 1653 m/sec), step length (mean SD THRS 0.74 m *vs* BFH-THR 0.76 m) and modification of the gravity center (mean SD THRS 31% *vs* BFH-THR 34%) (Table 2; Figure 2). No statistically significant difference was reported between THRS and BFH-THR groups, showing similar waking capabilities postoperatively. The standing test, the dynamic and static balancing and the proprioception measurements were almost similar in booth groups (mean THRS 316.2 mmq *vs* BFH-THR 823.1 mmq). The results demonstrated a

Table 1. Comparison of demographic characteristics between groups.

	BFH	RS	P
Age	50.69±11.28	50.47±9.68	0.954
BMI	31.60±3.71	31.00±4.14	0.674
HSS preoperative	56.50±11.88	60.33±9.94	0.340
Visual analogue scale UP AND GO preoperative	7.00±0.73	7.30±1.29	0.429
VAS preoperative	3.50±0.52	3.73±0.80	0.339
WOMAC preoperative	65.58±10.89	72.36±10.16	0.104
SF36 PCS preoperative	35.13±7.44	38.70±7.20	0.185
SF36 MCS preoperative	37.05±5.01	32.50±9.44	0.101
UCLA HSS ACT preoperative	3.50±1.15	4.07±1.49	0.244
Gender (male/female)	11 (69%) / 5 (31%)	7 (47%) / 8 (53%)	0.285
Cause (OA/other)	11 (69%) / 5 (31%)	11 (73%) / 4 (27%)	1.000
Foot (right/left)	12 (75%) / 4 (25%)	12 (80%) / 3 (20%)	1.000

Table 2. Comparison of gait, balancing and proprioception results with statistical significances.

Parameter	Mean value	SD	P
Time			
BFH	53.98	7.89	0.042
RS	56.16	4.72	
Distance/surface			
BFH	2.18	0.84	0.001
RS	3.25	0.81	
The center of weight area			
BFH	130.08	31.20	0.03
RS	100.14	19.31	
Ecliptic Surface			
BFH	94.21	26.54	0.0005
RS	64.51	9.42	

non-significant improvement of proprioception (mean Rosenberg Rate THRS 0.94 *vs* BFH-THR 0.86, Rosenberg rate P>0.05) and balancing adaption for the THRS group (mean THRS 2.3 mm/sec *vs* BFH-THR 11.8 mm/sec). Functional tests demonstrated no significant difference between the two groups: time up and go (mean SD THRS 6.8 sec *vs* BFH-THR 7.5 sec), SF36 (mean SD THRS 52.7 *vs* BFH-THR 54.1/PHYSICAL 56.2 *vs* 53.4) and Womac (mean SD THRS 3.2 vs BFH-THR 2.9) (Tables 2 and 3). All patients rated their clinical result as good and were able to return to daily activities. Mean VAS values for pain was 2 (range 1-4). No surgical or other postoperative complications were reported.

Discussion

Nowadays, there is a growing interest for bone-conserving replacement procedures. Restoration of normal motion and gait patterns after THRS provides good clinical function and reduced wear.[1,25-27] Literature data support that THRS may offer certain advantages over THR in terms of conservation of femoral bone stock for future revision. However, bone density appears to decrease at 6 weeks and 3 months, suggesting that caution is required until bone density recovers.[28,29] Apart from minimal bone resection, additional theoretical advantages of THRS include less inflammatory debris and osteolysis, improved joint stability, and improved biomechanics.[1,14, 30]

To reduce early failures in large-bearing metal-on-metal hip resurfacing and replacement prostheses, surgeons must take into account several parameters including implant design, component size and proper acetabular component positioning. Earlier generations of THRS demonstrated high rates of failure due to excessive wear of their bearing surface materials. Aseptic loosening and femoral neck fractures, attributable to high stresses and poor surgical technique, have been reported as the most frequent causes of THRS failure.[31,32] Since that time, innovations in technique and design, mainly the introduction of thinner shelled metal-on-metal interfaces with higher tolerances, improved prostheses' functional outcomes. Recent studies on THRS show a five-year survivorship of 98% and successful functional outcomes of 94%.[32,33] Nevertheless, these results are similar to those reported for THR.[34] The advent of metal-on-metal (MoM) bearings has been a large factor in the early reports of success with THRS.[35,36]

Nowadays, THRS have regained popularity and became particularly attractive to active young adults with disabling hip arthritis.[37] Several comparative studies have been conducted to assess whether these prostheses offer better results than conventional THR.[14,38] Selected gait studies concluded that although both treatment options demonstrate trends toward functional recovery, gait impairment persisted with no significant differences between the conventional prosthesis and the resurfacing system.[25] Multiple midterm clinical results suggest that THRS represent a safe, effective alternative to conventional total hip arthroplasty, especially for younger, active patients.[34] Shrader *et al.* concluded that although both THR and THRS demonstrated trends toward functional recovery, the THRS demonstrated improved hip extension and abduction moments, simulating typical loading of the hip.[1] In another study, THRS were shown to have higher UCLA activity scores and better EuroQol quality of life scores.[37] Mont *et al.*, assessing gait in 15 patients with THRS, demonstrated a more physiological hip abduction angle and extension moment for his study group, compared to the THR. The gait analysis in this study showed that patients with THRS had an almost-physiological gait. There were no significant differences in hip abductor and extensor moments between the two study groups. Hip kinematics and functionality were better for the resurfacing hip arthroplasty

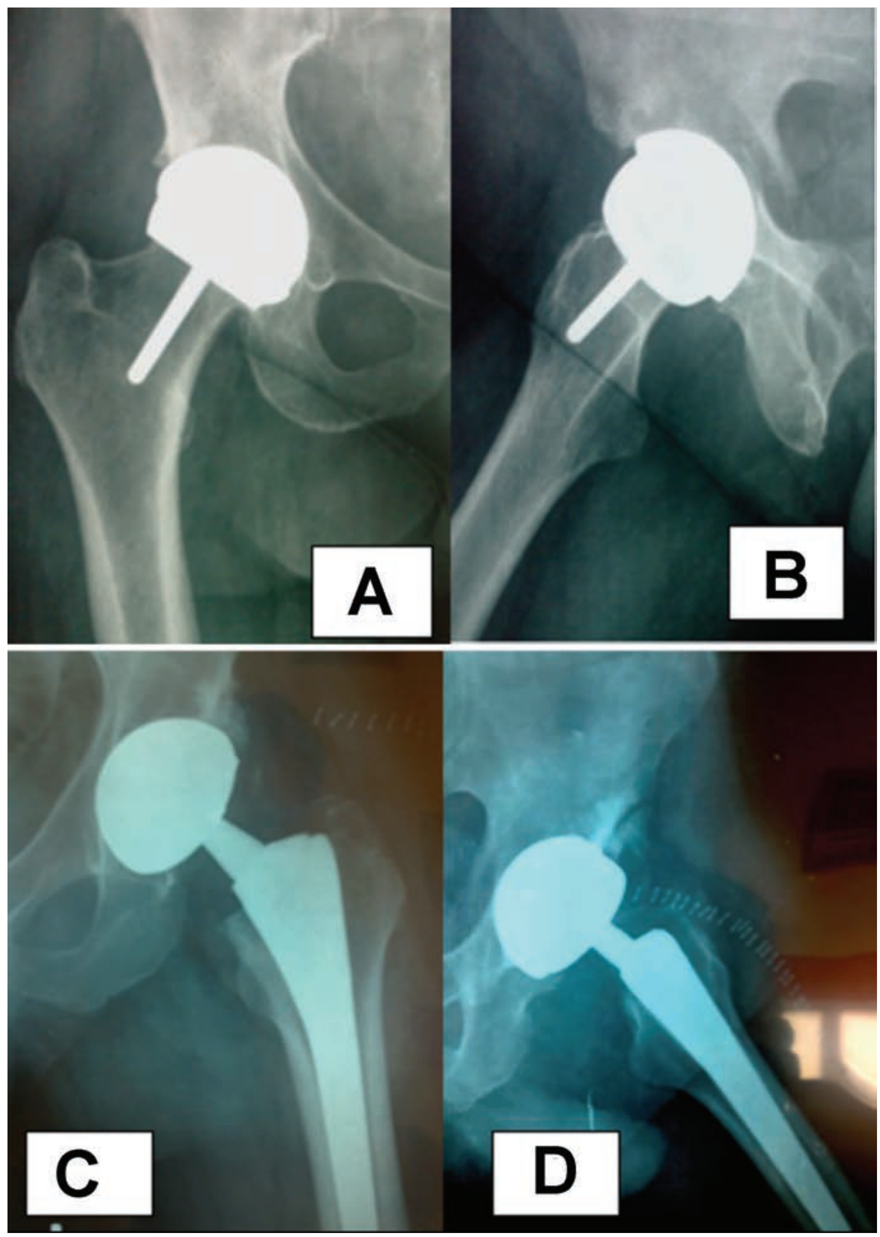

Figure 1. A,B) Anteroposterior and lateral hip x-rays of a patient submitted to total hip resurfacing replacement; C, D) anteroposterior and lateral hip x-rays of a patient submitted to big femoral head-total hip replacement.

Table 3. Comparisons of variables between groups.

Groups	BFH	P	RS	P	Median (IQR) % change pre-post BFH	RS	P between group
HSS							
Preoperative	56.50±11.88	<0.0005	60.33±9.94	<0.0005	73.76 (84.04)	73.58 (33.97)	0.545
Postoperative	93.75±3.61		95.67±1.95				
VAS UP and GO							
Preoperative	7.00±0.73	<0.0005	7.30±1.29	<0.0005	-85.71 (3.13)	-100.00 (11.11)	0.0005
Postoperative	1.00±0.01		0.33±0.49				
VAS							
Preoperative	3.50±0.52	<0.0005	3.73±0.80	<0.0005	-87.50(31.25)	-100.00(10.05)	0.050
Postoperative	0.50±0.50		0.13±0.35				
WOMAC							
Preoperative	65.58±10.89	<0.0005	72.36±10.16	<0.0005	37.68 (56.09)	29.02 (29.01)	0.090
Postoperative	93.35±34.79		94.55±3.01				
SF36 PCS							
Preoperative	35.13±7.44	0.001	38.70±7.20	<0.0005	35.92 (106.10)	47.38 (53.50)	0.770
Postoperative	49.63±9.85		54.41±3.03				
SF36 MCS							
Preoperative	37.05±5.01	<0.0005	32.50±9.44	<0.0005	21.51 (66.28)	90.66 (118.94)	0.001
Postoperative	48.60±7.05		56.13±3.64				
UCLA HSS ACT							
Preoperative	3.50±1.15	<0.0005	4.07±1.49	<0.0005	70.83 (144.6)	100.00 (65.00)	0.059
Postoperative	6.75±1.13		8.13±1.136				

group, however this could have been attributed to the size of the femoral head.[14]

Postural stability was also improved in THRS group. We believe that the anatomical preservation, the absence of femoral stems and the use of larger bearing components are responsible for these findings.[15] Total hip resurfacing maintained its advantage on muscle strength and walking velocity.[39] Both THR and metal-on-metal THRS groups showed improvements in HHS, pain, activity, ROM and had similar early complication and reoperation rates.[40]

Zhou *et al*. demonstrated that large diameter femoral heads THR provide better early gait restoration than conventional femoral heads (47). Queen *et al.,* in his comparative study on BFH-THR and THRS, reported a decrease of peak hip flexion, peak extension, and flexion at heel strike for both prostheses. However, the authors noted that peak hip extension and peak vertical ground reaction forces were decreased in the THR study group. Following a large-diameter THR or THRS, subjects do not display symmetric gait postoperatively for approximately 18 months. THR subjects demonstrated restricted hip extension and reduced limb loading when compared with THRS subjects.[11,17] Total hip replacement generates gait deficits that relate to physical subscales of the SF36. These findings provide guidance for physical therapy interventions, focused on gait performance after THR.[41] Literature data show that gait speed, postural balance, performance at most functional tests and clinical scores are similar in THRS and

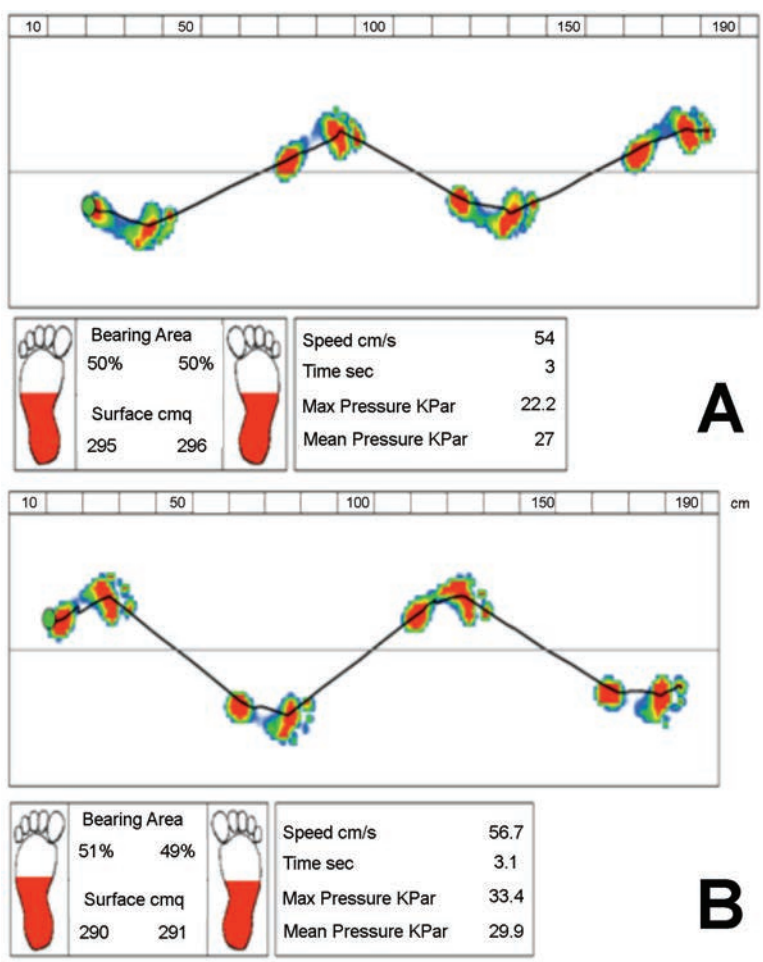

Figure 2. Gait analysis and parameters two years after total hip resurfacing replacement (A) and big femoral head-total hip replacement (B).

BFH-THR groups. This study shows that operated patients reached most control group values at 3 months postoperatively. Therefore, although a slight improvement in favor of THRS group was noted, no statistically significant differences were detected between the two groups.

Despite authors' efforts to ensure the validity of this study results, one can come across specific limitations. The follow-up period, although efficient for gait analysis, does not permit to draw safe conclusions on the prostheses' long-term results. Finally, due to the nature of this study, gait analysis prior to the onset of the hip disease, was not feasible for the patients of this study group.

Conclusions

This study shows that patients' gait after THRS and BFH-THR does not demonstrate symmetric characteristics to the contralateral, unaffected hip. Secondarily we were not able to demonstrate a significant difference between BFH-THR and THRS regarding gait analysis, postural balance and proprioception. Limited information has been published on the functional results following THRS revision. Recent data report worse functional results after revision of the femoral component of current-generation THRS prostheses.[42] Further research is required on the functional outcomes of THRS and BFH-THR revisions to confirm the advantage of bone conserving procedures.

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