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Hip Resurfacing Versus Large-Diameter Head Total Hip Arthroplasty. A Prospective Comparative Cohort Study on Early Functional Outcomes

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Abstract

Objective: There is no consensus whether hip resurfacing arthroplasty (HRA) performs better than a stem-type total hip arthroplasty (THA). Therefore, the aim of this prospective comparative matched-cohort study was to answer the following questions: 1) Do gait parameters differ between HRA and THA patients at 3, 6, and 12 months after surgery? 2) Are there differences in lower extremity muscle strength at the same time points? 3) Does the self-reported outcome using validated instruments improve similarly in both groups?

Methods: One experienced senior surgeon implanted either Durom HRA or CLS Spotorno THA in 34 male patients matched for anthropometric characteristics, preoperative scores and comorbidities. Preoperatively and at 3, 6, and 12 months, gait parameters, hip and knee muscle strength, clinical data and standardized outcome scores were assessed and compared between the two groups.

Results: No significant group differences were found for all gait and strength variables. Passive range of motion and mean scores for the SF-36, Harris Hip Score and UCLA activity scale improved significantly over time without differences between groups. At 12 months, more HRA than THA patients were reporting groin pain on impingement testing (20% versus 0%; P<0.05).

Conclusions: Excellent early outcomes were achieved by both HRA and THA in terms of score values, lower extremity muscle strength and gait parameters. No clinically relevant differences could be observed between HRA and THA patients. Groin pain after HRA remains a concern that warrants future investigation.

Keywords: Hip arthroplasty; Resurfacing; Walking function; Muscle strength; Questionnaires; Early outcome

Introduction

Hip resurfacing arthroplasty (HRA) has had encouraging short- and mid-term results for the treatment of hip osteoarthritis in young and active male patients [1-4]. Survival rates of up to 100% at 4 to 7 years have been reported [5]. Although concerns regarding large metal-on-metal bearings arose recently and worse results were published for some designs [4, 6-9], HRA is still regularly performed because it offers some conceptual advantages for younger patients such as a more physiologic load transfer on the proximal femur and preservation of femoral bone stock [10]. Up to now, there is however no clear consensus whether resurfacing indeed performs better than stem-type total hip arthroplasty (THA) in such patients. Regarding functional outcomes, some gait analysis studies suggested that patients achieve a more symmetrical gait pattern and increased gait speed after HRA compared to THA [11, 12] while others found no differences [13]. Though, there appears to be no known reason, why better functional outcomes should be achieved after HRA. It has been hypothesized that this could be attributed to the use of larger diameter heads and a more physiological reconstruction of the hip joint and muscle lever arms [14]. On the other hand, selection bias for more healthy and active patients might explain some of the better outcomes observed.

To address the issue of early functional outcomes and to control for the above-mentioned confounders we conducted a prospective comparative matched-cohort study and proposed the following research questions: 1) Do gait parameters differ between HRA and THA patients at 3, 6, and 12 months after surgery? 2) Are there differences in lower extremity muscle strength at the same time points? 3) Does the self-reported outcome using validated instruments improve similarly in the two groups?

Materials and methods

Patient cohorts

After appropriate ethical committee approval, 34 patients were enrolled from the preoperative waiting list of the Schulthess Clinic. Inclusion criteria were: male patient, age <65 years, Charnley class A hip osteoarthritis, BMI <32 kg/m^2, and University of California at Los Angeles (UCLA) activity score ≥5. Exclusion criteria were: any impairment of walking ability, known spinal disease or symptoms, known muscle disease, inflammatory arthropathy, drug use, severe deformity of the proximal femur and/or acetabulum, and previous trauma involving the lower extremities. Patients were informed about surgery and implant types in our country, and therefore the distribution to either the HRA group or THA group was done after comprehensive discussion with every patient on an individual basis and not randomized. The two cohorts were well matched for weight, height, BMI (Table 1), and preoperative scores (Table 2), but not for age. All patients provided written informed consent.

	HRA	THA	P value
N	19	15	-
Age (years)	49.9 ± 9.6	58.3 ± 7.3	0.009
Height (cm)	175 ± 6	176 ± 6	0.83
BMI (kg/m^2)	27.2 ± 3.9	28.6 ± 2.8	0.28
Weight (kg) at pre-op	83.6 ± 11.3	88.3 ± 10.0	0.21
Weight (kg) at 12 months	84.5 ± 12.1	88.7 ± 10.2	0.30

Table 1: patient characteristics; Values expressed as mean ± SD; Age, height and BMI refer to the preoperative state; HRA-hip resurfacing arthroplasty; THA-total hip arthroplasty.

	Pre-op	3 months	6 months	12 months
HHS				
HRA	64.7 ± 8.1	92.5 ± 8.7*	98.4 ± 2.5	99.1 ± 1.6
THA	60.5 ± 10.1	98.5 ± 2.8	94.4 ± 4.9	99.9 ± 0.3
SF-36 PCS				
HRA	38.8 ± 7.6	46.1 ± 7.1	46.4 ± 11.2	51.5 ±5.3
THA	38.9 ± 10.5	46.7 ± 10.8	45.3 ± 13.2	46.4 ± 11.9
SF-36 MCS				
HRA	63.2 ± 3.7	58.6 ± 7.2	60.6 ± 5.3	58.3 ± 2.5
THA	58.5 ± 8.2	57.1 ± 6.0	57.3 ± 4.8	56.0 ± 4.1
UCLA				
HRA	5.2 ± 1.1	6.9 ± 1.2	7.7 ± 1.0*	8.0 ± 1.4
THA	5.7 ± 1.7	7.1 ± 1.3	7.0 ± 1.4	7.6 ± 1.4
*difference between HRA and THA significant at P<0.05.				

Table 2: outcome score results; Values presented as mean ± SD; HRA-hip resurfacing arthroplasty; THA-total hip arthroplasty; HHS-Harris Hip Score; SF-36-Short Form 36; PCS-physical component scale; MCS-mental component scale; UCLA-University of California at Los Angeles.

Surgical procedure and postoperative regimen

All HRA and THA procedures were performed by one experienced senior surgeon using the posterior approach. Exposure and closure was similar for both types of surgery. The Durom implant (Zimmer Inc., Warsaw, IN) was used in the HRA group. The THA group received a cementless CLS Spotorno stem (Zimmer) and the press-fit Allofit cup (Zimmer) with a polyethylene liner and a large ceramic head (32 or 36 mm). All patients underwent the similar postoperative protocol with weight-bearing as tolerated and crutch use for four weeks. A home program consisting of balance exercises, isometric muscle strengthening workouts and range of motion exercises was instructed before discharge [15].

Experimental protocol

All patients completed the prospective standard protocol that included on-site visits with the assessment of gait parameters, hip and knee muscle strength and clinical status at baseline (the day before surgery), 3, 6, and 12 months after surgery, respectively.

Assessment of gait parameters

Spatiotemporal parameters of gait were measured with the use of an electronic mat (GAITRite, CIR Systems Inc., Clifton, NJ), which has been shown to provide valid and reliable data [16, 17]. The instrumented mat used in this study (thickness 6 mm; total length 823 cm) has an active sensor area of 732 cm (length) x 61 cm (width). The active area contains 27,648 pressure sensors arranged in a grid pattern with a spatial resolution of 1.27 cm and a sampling frequency of 80 Hz. Patients wore a comfortable pair of flat-soled walking shoes, and were required to walk at two different speeds: self-selected comfortable ("walk at a pace that is comfortable for you") and fast ("walk at a pace that is faster than you would normally walk"). Before data collection patients practiced walking over the mat at both velocities to familiarize themselves with the testing procedures. Each trial began and ended approximately 2 m from the mat so that a constant gait pattern was maintained. Three trials were recorded for each patient and for each velocity (normal and fast), and the average was used for subsequent analysis. Data from the activated sensors was collected by a series of on-board processors and transferred to a personal computer by way of an interface cable. A dedicated software (GAITRite Gold, Version 3.2b, CIR Systems Inc.) was used to process the data into footfall patterns and to calculate the following gait parameters: walking speed (cm/s), step length (cm), double support time (s), and toeing out (°). Only the data of the operated limb were retained.

Assessment of hip and knee muscle strength

Isometric maximal voluntary contraction (MVC) strength of the involved hip abductors and hip adductors (randomly presented) was measured using an isokinetic dynamometer (Biodex, Shirley Corporation, NY). Patients were standing next to the dynamometer lever arm, and were allowed to put their hands on the dynamometer chassis for body stabilization. The knee of the tested limb was fully extended during the MVCs and the tested hip was at 10° of abduction. The center of the dynamometer pad was located 5 cm proximal to the lateral (hip abduction) or medial (hip adduction) femoral condyle. Patient whole-body position was consistently checked during MVC trials to ensure minimal pelvic rotation and minimal flexion and rotation of the hip joint. After having received standardized instructions, patients were asked to complete several familiarization trials that were followed by two MVCs per muscle group, with 1 min of rest in-between. Patients were instructed to produce their maximal strength for 4-5 s, without any concern for the rate of force development. For both hip abductors and hip adductors, gravity-corrected MVC torque traces were recorded at a sampling rate of 100 Hz. The highest MVC torque normalized to body weight (Nm/kg) was retained.

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Isometric MVC strength of the involved knee extensors and knee flexors (randomly presented) was measured using an adjustable dynamometer chair instrumented with a strain-gauge system (Good Strength, Metitur, Jyvaskyla, Finland). Patients were seated comfortably on the dynamometer chair with the hip flexed at approximately 90°. The knee of the tested limb was fixed at 60° flexion (0° = knee fully extended), and the distal shin pad of the dynamometer was attached 3-5 cm proximal to the lateral malleolus by using a strap. To minimize extraneous body movements, straps were applied across the chest, pelvis, and mid-thigh. Patients were asked to position their arms across the chest, and to warm up by performing a series of submaximal (20% to 80% of the estimated maximum effort) isometric contractions of the knee extensor and flexor muscles. Patients were also asked to complete one quasi-maximal practice repetition before each MVC. Two MVCs were then performed for knee extensors and knee flexors (separated by 1-min rest periods). Patients were asked to produce their maximal strength progressively and to maintain it for 4-5 s. The investigators provided standardized verbal encouragement to the patient throughout the testing protocol. For both knee extensors and knee flexors, gravity-corrected MVC force traces were recorded at a sampling rate of 100 Hz. The highest MVC force normalized to body weight (N/kg) was retained.

Clinical assessments

Passive range of motion for hip flexion and internal rotation in 90° of hip flexion as well as pain on impingement testing were determined by one of the authors who was not involved in surgery. Additionally, the Harris Hip Score (HHS), the Medical Outcomes Study 36-item Short Form Health Survey (SF-36) [18] and the UCLA activity scale [15, 19] were completed.

Statistics

All functional outcomes were submitted to two-way ANOVAs with group (HRA vs. THA) as the between-participant factor and time (0, 3, 6, 12 months) as the within-participant factor. Analysis of covariance was also used to control for age differences between groups (see Table 1). For both patient groups, longitudinal changes in range of motion were examined using the Wilcoxon test. Differences in patient-reported pain during the impingement test were examined using the Fisher test for group differences (HRA vs THA) and the McNemar exact test for longitudinal changes (pre vs. post). Significance was set at P≤0.05.

Results

Gait parameters

For all spatiotemporal gait parameters obtained at normal (Figure 1) and fast (Figure 2) velocity, no group main effect was noticed (P>0.05), while time main effect was significant (P<0.001). Compared to pre-operative data, most gait parameters showed an improvement already 3 months after surgery, except walking speed, step length and double support time at fast velocity in THA patients. A continuous improvement occurred until 12 months post-surgery. A significant group by time interaction was observed for step length (P=0.035) in the fast-velocity but not in the normal-velocity condition. Similar results were obtained after controlling for age (data not presented).

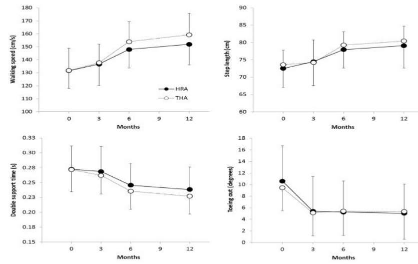

Figure 1: Gait parameters at normal velocity by group at month 0 (pre-op), 3, 6 and 12 (post-op). A: walking speed; B: step length; C: double support time; D: toeing out. Mean data and SD. No significant group by time interaction was observed.

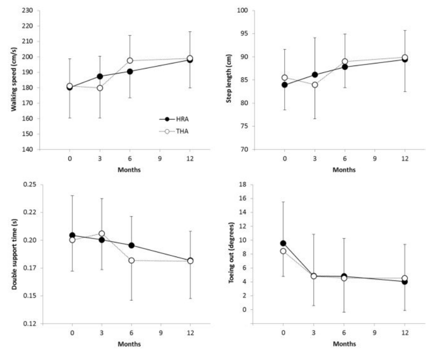

Figure 2: Gait parameters at fast velocity by group at month 0 (pre-op), 3, 6 and 12 (post-op). A: walking speed; B: step length; C: double support time; D: toeing out. Mean data and SD. A significant group by time interaction was only observed for step length (P=0.035).

Hip and knee muscle strength

For all hip and knee muscle strength outcomes (Figure 3), no group main effect was noticed (P>0.05), while time main effect was significant (P<0.05). Compared to baseline, MVC strength of all muscle groups, except knee extensors in HRA patients, showed a decline at 3 months after surgery. Baseline values were achieved at 6 months post-surgery. A significant group by time interaction was observed for knee extensor strength (P<0.05). Similar results were obtained after controlling for age (data not presented).

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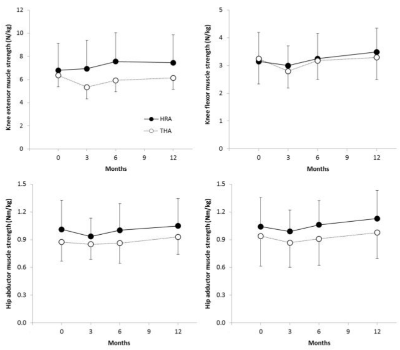

Figure 3: Hip and knee muscle strength by group at month 0 (pre-operative), 3, 6 and 12 (post-operative). A: knee extensors; B: knee flexors; C: hip abductors; D: hip adductors. Mean data and SD. A significant group by time interaction was observed for knee extensor muscle strength (P<0.05).

Clinical results and outcome scores

Hip flexion improved from 97° preoperatively to 101° at 12 months in the HRA cohort (P<0.01), and from 89° to 95° in the THA cohort (P<0.01). Internal rotation in 90° of hip flexion improved from 28° to 51° in the HRA cohort (P<0.01), and from 15° to 45° in the THA cohort (P<0.001). At 12 months, more HRA than THA patients were reporting groin pain on impingement testing (20% versus 0%; P<0.05). A significant group by time interaction was found for HHS (P=0.02) with higher scores at 3 months for THA patients (P<0.05; Table 2). No group differences were found at the other time points. There was no significant interaction for SF-36 PCS (P=0.573) and MCS (P=0.447). The main factor time was significant for SF-36 PCS (P<0.001) showing an improvement at every follow-up compared to baseline (P<0.001 at 3 and 12 months; P=0.014 at 6 months). The main factor time was also significant (P=0.004) for SF-36 MCS indicating an improvement at every follow-up compared to baseline (P<0.001 at 12 months; P=0.024 at 3 months). There was no significant interaction for the UCLA activity scale (P=0.104), while the main factor time was significant (P<0.001) with higher scores at each follow-up compared to baseline (P<0.001).

Discussion

Based on current evidence in the literature, there is no consensus whether HRA or THA would result in different functional outcomes. Some studies suggest that patients after HRA would have better functional outcomes than patients after conventional THA [13, 14, 20] while other authors found no differences [21]. However, in these studies not all patients were assessed preoperatively or at the first follow-up after 3 months, which makes it difficult to detect potential group differences during the early rehabilitation period. The present study was therefore designed to determine potential differences in early functional outcomes between two matched cohorts of patients undergoing either HRA or THA for the treatment of hip osteoarthritis.

The present results suggest that there are no or only marginal differences in objective functional outcomes between HRA and THA. HRA patients showed a better improvement in knee extensor muscle strength after surgery, but they started at a slightly higher level. Similar baseline results were found for the hip abductors and adductors. These differences can hardly be explained by the type of implant and might possibly be due to inter-group differences in age, since the HRA group was nine years younger on average [22, 23], even if we accounted for that factor with the ANCOVA, and/or in physical activity level at baseline. As could be expected due to the use of crutches and postoperative restrictions, lower extremity muscle strength generally decreased in both groups from preoperatively to the 3 months follow-up. Full recovery was seen after 6 months with only slight improvements thereafter. More interestingly, walking function as assessed by quantitative gait analysis significantly improved over time and HRA patients showed an improvement already at 3 months. Fast walking is supposed to be more challenging than walking at normal speed, since it requires more strength and coordination abilities. Schmitz et al. [24] stated that there are age-related changes in neuromuscular function that could affect walking strategy, thereby contributing to a reduced push off power at fast walking speed. But other studies state that there is only a very small age-dependency of these parameters and the effect of age could be attenuated by the individual ability of inter-limb coordination [25, 26]. Aqil et al. [27] suggested that arthroplasty implants may have an impact on gait characteristics, such as weight bearing and push off force, which may be more evident for fast walking and walking uphill and that HRA may enable a more normal gait. In our patient group the differences were not significant enough to suggest an impact of the implant on gait parameters and we rather believe that the interaction was caused by potential differences in coordination.

Clinically, early outcomes were excellent in both groups and no substantial differences could be observed between the two cohorts for the HHS, SF-36 or UCLA scores. Interestingly, THA patients achieved the greatest improvement already within the first 3 months, without significant changes in SF-36 and HHS values thereafter, and a slight increase in activity levels after 12 months. HRA patients also achieved their largest improvements within the first 3 months but still improved thereafter with the highest values found at 12 months. However, these observations might have no or little clinical relevance since the differences in mean score values were, as already stated, rather minimal. More relevant seems to be the finding of persistent groin pain in a significant proportion of HRA patients at the last follow-up. While almost all patients experienced pain on internal rotation in flexion before surgery, none of the THA patients were symptomatic after 12 months vs. 20% for HRA patients. Groin pain has been recognized as a problem following HRA. Bin Nasser et al. [28] reported that 18% of their 116 patients had residual groin pain after HRA, but these authors could not identify the underlying mechanisms. Lavigne and colleagues [29] speculated that a local inflammatory reaction to the metal-on-metal bearing could be responsible for pain. Also, the worse head-neck offset-ratio in HRA hips could lead to capsular impingement and therewith induce pain [30]. Finally, cup size, cup position and the cup design cut favor psoas tendon impingement in HRA hips [30, 31]. Although the design of the cups used in this series did not differ significantly between the two groups of patients, the HRA Durom cup has sharp fins at its outer periphery and these might potentially cause irritation of the psoas tendon if the cup has not been fully seated underneath the anterior acetabular wall. However, cup anteversion has not been determined in this study and the latter hypothesis remains therefore speculative. Passive range of motion improved in both groups; HRA started off with a slightly better range of motion preoperatively, but at 12 months there was no significant difference between patient groups.

This study has some limitations. First of all, age was not perfectly matched between HRA and THA, and the level of physical activity was not controlled at baseline. The group by time interactions we observed for muscle strength and gait parameters at fast velocity might therefore have been biased by the above-discussed differences in age and/or physical activity level. Second, the study was not randomized since patients in our country are usually well educated about the operative procedures and want to know before the surgery which type of implant they will receive. Finally, the study cohort was rather small. On the other side, this study has several strengths. First, except for age, both cohorts were very uniform and well matched. Surgery-related confounders could be excluded since all procedures were undertaken by one senior surgeon experienced in both types of surgeries. Furthermore, all patients underwent the same postoperative treatment protocol and were followed prospectively. Finally, to the best of our knowledge this is the first study that prospectively compared objective gait and muscle function parameters between HRA and THA patients using valid and reliable methods [16, 32, 33].

In conclusion, excellent early outcomes were achieved by both HRA and THA patients in terms of score values, lower extremity muscle strength and gait parameters. No clinically relevant differences could be observed between HRA and THA subgroups. Groin pain after HRA remains a concern that warrants future investigation.

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