Gait analysis of patients with metal-on-metal resurfacing hip arthroplasty compared with big-femoral-head total hip arthroplasty

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ABSTRACT

الأهداف: تحليل أنماط المشية لدى المرضى الذين أُجريت لهم عملية إعادة تغطية الأسطح البالية لمفصل الورك، ومقارنة نتائج هذه العملية بنتائج عملية رأب مفصل الورك ذو الرأس الفخذية الكبيرة وذلك بعد مرور عام من إجرائها.

الطريقة: أُجريت هذه الدراسة الاسترجاعية في مستشفى الشعب السادس والذي يتبع لجامعة جياوتونغ شنغهاي، شنغهاي، الصين وذلك خلال الفترة من يونيو 2006م إلى مارس 2009م، حيث تم تقسيم المشاركين إلى مجموعتين: المجموعة التي أُجريت لها عملية إعادة تغطية الأسطح البالية لمفصل الورك (30 مشاركاً)، ومجموعة عملية رأب مفصل الورك ذو الرأس الفخذية الكبيرة (30 مشاركاً). لقد تم قياس كلاً من أنماط المشية ومدى الحركة باستخدام نظام فيكون لتحليل المشية، ومن ثم استخدمت نتائج التحليل من أجل حساب نسب أنماط المشية ومدى الحركة في الأجزاء التي أُجريت عليها العملية، وفي الأجزاء المقابلة.

النتائج: أشارت نتائج الدراسة إلى أنه لم يكن هناك اختلافاً واضحاً بين المجموعتين فيما يخص كلاً من: نسب أنماط المشية، ومؤشر درجات المستشفى للجراحة الخاصة، بالإضافة إلى مؤشر جامعة كاليفورنيا في لوس أنجليس، وبالمقابل فقد كان هناك اختلاف كبير في نسب مدى الحركة بين تلك المجموعتين. وقد أظهرت نتائج مجموعة عملية إعادة تغطية الأسطح البالية لمفصل الورك بأن نسب مدى الحركة في مفصل الورك الذي أُجريت عليه العملية كانت مشابه للأجزاء المقابلة (انثناء الورك وتمدده: p=0.007، تقارب مفصل الورك وتباعده: p=0.005، تدوير مفصل الورك: p=0.006، انثناء مفصل الركبة وتمدده: p=0.037).

خاتمة: أثبتت الدراسة بأن أنماط المشية لدى المرضى الذين أُجريت لهم عملية إعادة تغطية الأسطح البالية لمفصل الورك والمرضى الذين خضعوا لعملية رأب مفصل الورك ذو الرأس الفخذية الكبيرة كانت قريبة للقيم الطبيعية وذلك بعد مرور عام من إجراء العملية. وفيما يخص عامل الوقت فقد كانت نسب مدى الحركة لدى مرضى عملية إعادة تغطية الأسطح البالية لمفصل الورك أكبر من نسب مرضى عملية رأب مفصل الورك ذو الرأس الفخذية الكبيرة وذلك أثناء المشي.

Objectives: To evaluate gait patterns in patients with metal-on-metal resurfacing hip arthroplasty (RHA) compared with big-femoral-head total hip arthroplasty (BHA) at one year postoperatively.

Methods: In this retrospective comparative observational study, 2 groups of 30 resurfacing hip arthroplasty (RHA) and big-femoral-head total hip arthroplasty (BHA) patients participated between June 2006 and March 2009 in the Sixth Affiliated People's Hospital, Shanghai Jiaotong University, Shanghai, China. Gait parameters and range of motion (ROM) in gait cycles were measured by Vicon gait analysis system and were used to calculate operated/contralateral ratios.

Results: No significant difference was found between gait parameter ratios, Hospital for Special Surgery Score (HSS), and University of California at Los Angeles Score (UCLA) of the 2 groups. However, there was significant difference between ROM ratios in gait cycles. Range of motions of operated hip joint were more similar to that of contra-lateral side in RHA group (hip flexion/extension p=0.007, hip abduction/adduction p=0.005, hip rotation p=0.006, knee flexion/extension p=0.037).

Conclusion: Gait parameters of patients who underwent RHA and BHA are approaching to normal values at one year postoperatively. At the time point, ROMs of RHA patients are larger than that of BHA patients during walking.

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Hip arthroplasty can relieve pain, restore joint function and improve the quality of life of patients. Hip arthroplasty is considered to be one of the most successful orthopedic procedures.[1] But, dislocation and osteolysis accompany with regular diameter metal-on-polyethylene hip arthroplasy remain to be the major complications. Metal-on-metal resurfacing hip arthroplasty (RHA) and big-femoral-head total hip arthroplasty (BHA) both using a larger diameter femoral head have become increasingly popular, especially for young patients who require higher activity and quality-of-life along with greater range of motion. Both at home and abroad, related clinical research is popular recently. Although there is a concern on short-term complications related with metal-on-metal articulation recently, metal-on-metal articulation allows the use of a larger femoral head to reduce dislocation.[2-4] A well-functioning metal-on-metal articulation, either resurfacing or total hip, has no risk of fracture with unlimited activity. The 20 years of experience with the McKee-Farrar implant and the 7 years of experience with hip resurfacing suggest a possible 20-year survivorship of more than 80%.[5-7] In our study, gait data of 60 patients who underwent RHA and BHA were collected after a year postoperatively using Vicon gait analysis system. We wonder if there is a significant difference on clinical function between RHA and BHA.

Methods. We retrospectively evaluated 60 patients with unilateral hip disease who underwent metal-on-metal RHA or BHA between June 2006 and March 2009 in the Sixth Affiliated People's Hospital, Shanghai Jiaotong University, Shanghai, China. The Hospital Ethics Committee approved the research protocol. All involved hips showed moderate to severe degeneration, whereas the contralateral hips were free of disease. There was no patient with specific anatomy characterized by low femoral offset such as Legg-Calve´-Perthes disease that could influence the femoral offset. The following exclusion criteria were applied: 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. All participants gave their written consent and the study received an ethical approval from the review boards of all involved institutions. The patients were divided into 2 groups: RHA group (30 patients) and BHA group (30 patients). The demographic data in the RHA group were similar to the BHA group (**Table 1**). The minimum follow-up was 12 months (mean, 13 months; range, 12-16 months) in both groups. All patients received general anesthesia and were positioned in the lateral decubitus position. Four surgeons performed the surgeries through a posterolateral surgical approach in both groups. All 4 surgeons had considerable experience with the RHA and BHA systems used in this study. For the BHA, the standard techniques proposed by the manufacturer for insertion of the Profemur® Z femoral stem (Wright Medical Technology, Arlington, TN, USA) were followed. In the RHA group, proper femur mobilization allowed preparation and cementation of the corresponding Conserve Plus® femoral component (Wright Medical Technology, Arlington, TN, USA). For both groups, the Conserve® acetabular cup (Wright Medical Technology, Arlington, TN, USA) was inserted as proposed by the manufacturer. Metal-on-metal femoral heads with an average size of 44 mm were used in RHA group, while 42 mm in BHA group.

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

Gait analysis was performed in a dedicated gait laboratory at one year postoperatively. The gait assessments consisted of 10 walking trials at normal speed on a 6-m walkway with 2 centrally located force plates (Kistler 9286, Winterthur, Switzerland) (**Figure 1**). The normal speed was set at the subject's usual self-selected comfortable speed. Sixteen reflecting markers placed on the specific anatomic landmarks on the lower limbs were captured at 60 Hz with an 8-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 kinetic and kinematic parameters, as well as ROM in gait cycles (**Figures 2a-2c**). Anteroposterior radiograph of the pelvis and lateral radiograph of the hip joint were taken preoperatively and at all follow-up

Table 1 - Demographic characteristics of participants.

Demographic data	RHA	BHA
Gender (Male/Female)	4/26	2/28
Age (years)	51.2 (30-67)	52.6 (31-63)
AVN	12	10
DDH	11	13
OA	7	7

RHA - resurfacing hip arthroplasty; BHA - big-femoral-head total hip arthroplasty; AVN - avascular necrosis of the femoral head; DDH - developmental dysplasia of the hip, OA - osteoarthritis

Figure 1 - A subject was walking at normal speed on a 6 meter walkway with reflecting markers placed on the specific anatomic landmarks on the lower limbs.

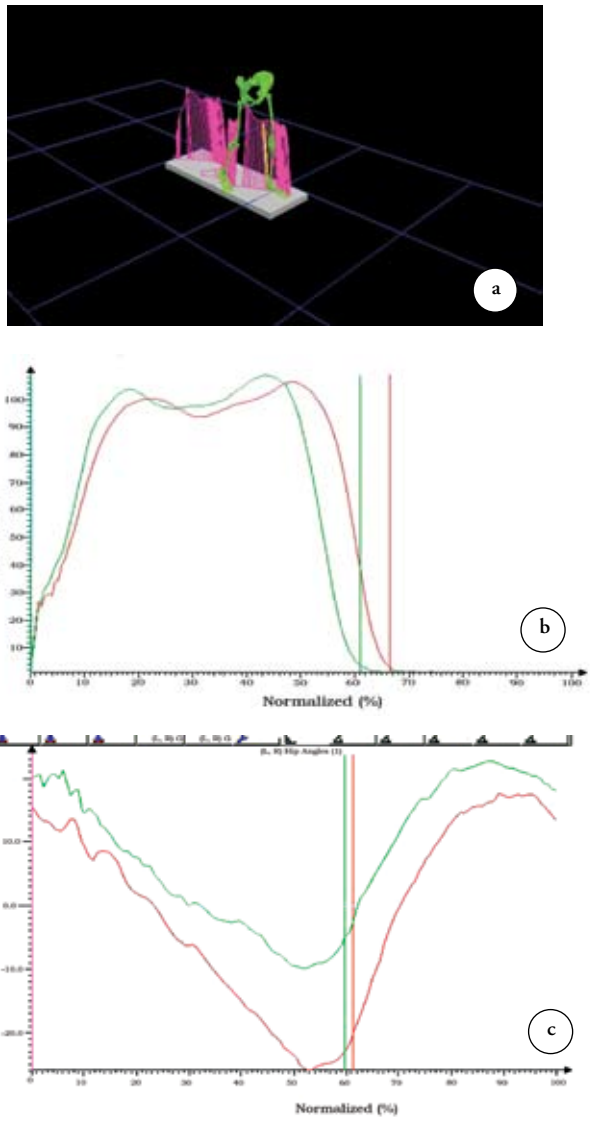

Figure 2 - a) Skeleton representation after a right resurfacing hip arthroplasty. b) Vertical ground reaction force composite graph in a gait cycle. Red line = left lower limb; green line = right lower limb. c) Hip ROM (flexion/extension) composite graph in a gait cycle. Red = left lower limb; green = right lower limb. ROM: range of motion

evaluations (3, 6, and minimum 12 months) (**Figures 3a & 3b**).

At minimum of one year postoperatively, Hospital for Special Surgery Score (HSS) and University of California at Los Angeles Score (UCLA) were also completed. High score on the UCLA and HSS activity scores indicates better outcome. The kinetic and kinematic selected parameters, as well as ROMs of the patients were assessed, compared to the operated with the contralateral side and calculated the ratios. We determined differences between the 2 groups by using independent t-test. Two-sided significance tests were used throughout the analysis. All analyses were performed using SPSS Version13.0 (SPSS Inc, Chicago, IL, USA).

Results. At one year postoperatively, both groups showed similar UCLA and HSS activity score (p>0.05) (**Table 2**). All patients were satisfied with their recovery. No patient in either group reported thigh pain or other uncomfortableness. No signs of acetabular or femoral component loosening were observed. Operated/contralateral ratio values of cadence, single support, foot off, peak value of vertical ground reaction force (VGRF) and hip and knee ROMs approached to one, which indicated that all assessed parameters of the operated side were closely similar to the contralateral side. There were no differences between the groups for the ratios of cadence, single support, foot off, VGRF (p>0.05) (**Table 3**). We found differences between the groups for hip and knee ROMs (**Table 4**). As for hip range of flexion/extension, abduction/adduction, rotation and knee range of flexion/extension, the RHA group performed better at 12 months postoperatively compared with the BHA group (hip flexion/extension p=0.007, hip abduction/adduction p=0.005, hip rotation p=0.006, knee flexion/extension p=0.037). No difference was found between the groups for knee range of abduction/adduction, rotation.

Discussion. There are a variety of tools for postoperative assessment of joint surgical treatments, of which gait analysis is the most objective. Gait analysis

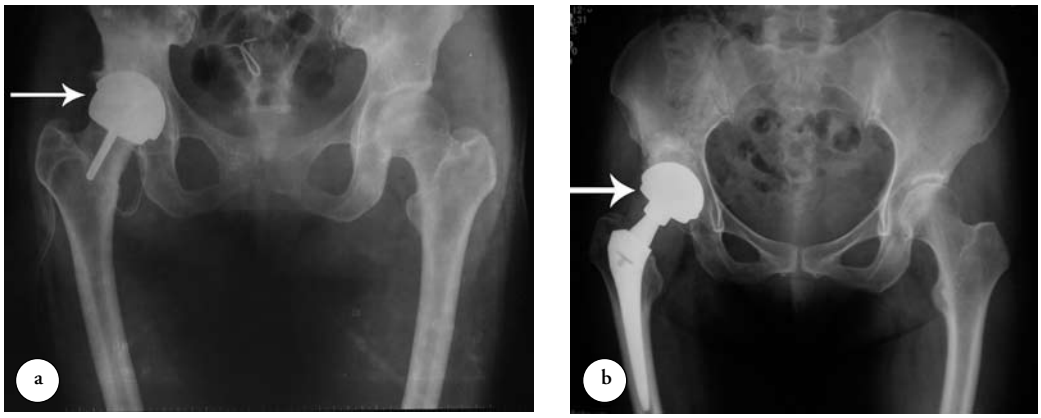

Figure 3 - **a**) Anteroposterior radiograph of the pelvis of a patient who underwent resurfacing hip arthroplasty on the right hip at one year postoperatively. **b**) Anteroposterior radiograph of the pelvis of a patient who underwent big-femoral-head total hip arthroplasty on the right hip at one year postoperatively.

Table 2 - Analysis of hip HSS and UCLA activity scores.

Hip arthroplasty	BHA	RHA	*P*-value	95% confidence interval of the difference	
HSS	54.93 ± 2.49	55.2 ± 2.24	0.659	-1.4705	0.9372
UCLA	7.87 ± 0.74	7.93 ± 0.70	0.718	-0.4342	0.3009

RHA - resurfacing hip arthroplasty, BHA - big-femoral-head total hip arthroplasty, HSS - Hospital for Special Surgery Score, UCLA - University of California at Los Angeles Score

Table 3 - Analysis of gait parameters' ratios between the groups for the ratios of cadence, single support, foot off, and VGRF.

Parameter	BHA	RHA	*P*-value
Cadence	0.9987 ± 0.0256	0.9979 ± 0.0327	0.918
Foot off	0.9858 ± 0.0676	0.9987 ± 0.0420	0.378
Single support	1.0072 ± 0.1703	1.0135 ± 0.0635	0.852
Peak value of VGRF	0.9779 ± 0.0504	1.0015 ± 0.0642	0.118

RHA - resurfacing hip arthroplasty, BHA - big-femoral-head total hip arthroplasty, VGRF - vertical ground reaction force

Table 4 - Analysis of hip and knee range of motion ratios.

ROM	BHA	RHA	*P*-value
Hip flexion/extension	0.8615 ± 0.2399	1.0323 ± 0.2308	0.007
Hip abduction/ adduction	0.7824 ± 0.2091	0.9747 ± 0.2932	0.005
Hip rotation	0.8162 ± 0.2083	1.0558 ± 0.4061	0.006
Knee flexion/ extension	0.9472 ± 0.0796	1.0027 ± 0.1178	0.037
Knee abduction/ adduction	1.1481 ± 0.5615	1.2152 ± 0.7023	0.684
Knee rotation	1.0322 ± 0.4706	1.1663 ± 0.5817	0.330

RHA - resurfacing hip arthroplasty, BHA - big-femoral-head total hip arthroplasty, ROM - range of motion

boomed with the rapid development of computer technology during the past 2 decades, and is now increasingly used in the evaluation of the efficacy of hip replacement.[7-10] Human body kinematics, kinetics and dynamic electromyography data can be collected through gait analysis systems to quantitatively assess patients' function. Different types of replacement, surgical approaches and other factors impacting on the results can be compared objectively.[10-14] Thus, gait analysis helps surgeons to choose procedures and rehabilitation programs. With continuing advancement in biomechanics and information processing, gait analysis system becomes more prolific, affordable, and important in hip arthroplasty. Patients are always expecting for better quality of life after THA, which make it necessary to constantly develop arthroplasty techniques in order to produce longer prosthesis survival and better function.[11] Compared with traditional THA, metal on metal RHA and THA making use of a large-diameter femoral head effectively decrease wear particle generation, reduce impingement and ensure large range of motion, which can meet young and active patients' requirement. Moreover, a major advantage of RHA is that bone stock for future revision is retained, which young and active patients prefer. In terms of operative time, blood loss, and clinical success rate, conversion to a THA is more similar to a primary THA than to a revision procedure.[15] Current results of comparative study on RHA and traditional THA are controversial. Shimmin et al[16] found no difference in

gait characteristics between 14 RHA and 12 THA. On the contrary, several studies had shown that gaits in patients with RHA were closer to normal than they were in patients with THA.[17,18] Mont et al[10] reported improved gait parameters (speed of walking, abduction moments) after RHA when compared to standard hip arthroplasty and osteoarthritic hips in their study. Shrader et al[19] reported that patients who underwent RHA had greater hip abduction moments, higher clinical survey scores, and greater symmetry in muscular activation 3 months postoperatively in comparison with those who had undergone THA. Zhou et al[11] collected gait data for primary THA using 28 mm metal-on-polyethylene heads (conventional group) and for THA (large head replacement group) using metal-on-metal femoral heads with an average size of 45 mm. The results suggested that large diameter femoral heads in THA provide better early gait restoration than conventional femoral heads. Lavigne et al[12] found better gait measurements in patients with RHA and with THA using large-diameter heads than in those with standard THA. However, the comparative study on the postoperative functional effects of RHA and BHA based on gait analysis is scarce. Therefore, we compared gait parameters, ROMs and activity scores of 2 groups of patients. There were no differences between the groups for cadence, single support, foot off, peak value of VGRF, as well as activity scores. These assessed data were closely similar to normal. Davis et al[20] pointed out in a retrospective study that after THA, ROM of the affected hip is an important factor that affects the function of the affected limb, and the former is positively correlated with the latter. Larger ROM enables the replaced hip to flex and internally rotate more in both stance and swing phases in a gait circle. This not only increases walking speed and stride distance but also allows patients to walk in a way that conserves more energy. Our finding proved this point by subjective and objective evaluation tools.

To hip joint arthroplasty, ideal function restoration depends on better reconstruction of femoral offset and equality of leg length.[13,14,21] Because of reduced bone resection, RHA may allow the anatomic preservation of the hip biomechanics that may lead to a more physiologic load transfer with respect to THA. A large-diameter femoral head predictably increases stability and decreases the dislocation rate postoperatively, and also provides a larger range of motion by delaying impingement between the femoral neck and the rim of the acetabular component. Gait parameters and ROMs of patients in our study were all similar to normal (operated/contralateral ratio values approach to one). Besides this, high score on the UCLA and HSS activity scores proved that a large-diameter femoral head could allow a more precise reconstruction of hip joint. In our study, we found that hip range of flexion/extension, abduction/adduction, rotation and knee range of flexion/extension of patients in RHA group performed better at 12 months postoperatively compared with the BHA group ($p>0.05$). Compared with BHA group, ROMs of operated hip joint in RHA group were more similar to that of contralateral side during walking. It may be due to the preservation of the femoral head and neck in the RHA which allows a more physiologic load transmission to the proximal femur as well as a better proprioception. In addition, subjective factors can affect gait restoration of the operated limb to some extent. Young and active patients who underwent RHA may expect for higher quality of life and may be more aggressive with their rehabilitation procedure.

There are several limitations in our study. Restricted by objective conditions, gender differences of the 2 groups could not be eliminated. Neither researchers nor patients were kept blinded, so subjective factors might influence the results. Enrolled patients were evaluated only at one time point after the hip arthroplasty procedure. In the following study, we will prospectively compare postoperative gait parameters with preoperative parameters. The sample of this study is relatively small. A large sample multi-center trial will make it possible to categorize patients in accordance with the existing pathology and ensure the results be more valuable. We will keep on following up these patients for middle and long term results.

In conclusion, gait of patients who underwent RHA and BHA are approaching to normal at one year postoperatively. Range of motions of RHA patients are larger than that of BHA patients during walking. Clinical evaluation supports the use of metal-on-metal RHA and BHA in young active patients.

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