

Original Article

Comparison of postoperative gait in patients with large- or standard-diameter-femoral-head hip arthroplasty

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Abstract: Objective: The aim of this study was to investigate differences in the gait patterns of patients with ceramic-on-ceramic large-diameter-femoral-head hip arthroplasty (LHA) and those with standard-diameter-femoral-head hip arthroplasty (SHA) within one year after surgery. Methods: Between October 2012 and March 2014, 30 patients who had undergone LHA (36 mm) and 30 patients who had undergone SHA (28 mm) were selected. One year after surgery, postoperative gait analysis of each patient was performed with the Tecnobody gait analysis system, and gait parameters (ipsilateral/contralateral ratios for each patient) were measured. Results: Ipsilateral/contralateral ratios of step cadence, step time, proportions of the gait cycle accounted for by the single-leg stance phase and the swinging phase and the Harris score of the hip joint did not differ significantly between the two groups. However, ipsilateral/contralateral ratios of step length, gait velocity, hip flexion/extension, adduction/abduction, rotation, and knee flexion/extension were significantly higher in the LHA group than in the SHA group ($P < 0.05$). Conclusion: One year after surgery, gait parameters and joint range of motion were superior in patients who underwent LHA compared to those who underwent SHA. A large-diameter-femoral-head prosthesis may be more effective in the recovery of joint function in patients after surgery.

Keywords: Arthroplasty, replacement, hip, gait, range of motion, articular

Introduction

Artificial hip replacement surgery, one of the most successful surgical treatments, can effectively relieve pain, restore joint function, and improve gait and quality of life in patients [1-4]. Because of its long-term efficacy, in recent years it has been increasingly used in the treatment of young patients with hip disease. Because young patients have a high level of activity, which requires frequent use of the joints, use of large-diameter-femoral head total hip arthroplasty in young patients is gradually increasing. However, the traditional standard-diameter-femoral-head total hip replacement has been used for a long time and is still widely used. Three-dimensional gait analysis is widely used for objective gait assessment in clinical settings [5-8]. Although there are domestic and overseas studies on the ceramic-on-ceramic large-diameter-femoral-head hip prosthesis

and metal-on-polyethylene standard-diameter-femoral-head hip prosthesis [9-11], few studies have analyzed postoperative gait in patients undergoing ceramic-on-ceramic large-diameter-femoral-head hip arthroplasty (LHA) and standard-diameter-femoral-head hip arthroplasty (SHA). In this study, the Tecnobody three-dimensional gait analyzer was used for the gait analysis of patients who had undergone LHA or SHA within the first year after surgery, and differences in joint function between the two groups were compared.

Materials and methods

General data

Thirty patients who underwent LHA (36 mm) and 30 patients who underwent SHA (28 mm) between October 2012 and March 2014 and met the selection criteria were included in this

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study. Included patients were those who had undergone primary unilateral total hip arthroplasty and had an unequal leg length (< 10 mm), no other lower limb joint diseases or surgery, and no nervous system diseases. The LHA group included 13 male and 17 female patients aged 33 to 65 years (mean, 52.8 years). Of these 30 patients, 13 had avascular necrosis, eight had hip dysplasia, five had femoral neck fracture, and four had osteoarthritis. The SHA group included 11 male and 19 female patients aged 35 to 69 years (mean, 55.5 years). Of these 30 patients, 11 had avascular necrosis, seven had hip dysplasia, seven had femoral neck fracture, and five had osteoarthritis. The preoperative Harris score was 41.6 ± 12.4 in the LHA group and 42.8 ± 13.1 in the SHA group. This difference was not statistically significant. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Jining Medical College. Written informed consent was obtained from all participants.

Hip score standard (Harris score)

To score pain, we used a 44-point scale: 1) no or negligible pain, 44 points; 2) occasional pain that did not affect activities, 40 points; 3) mild pain with no effect on general activity and possible moderate pain on excessive activity that can be alleviated with aspirin, 30 points; 4) moderate pain that can be tolerated but often results in abandonment of some activities including general activities and work to a certain extent, requiring stronger painkillers than aspirin, 20 points; 5) severe pain with severe restriction of activities, 10 points; and 6) wasting disease, severe pain despite confinement to the bed, limping due to pain, or long-term confinement to the bed, 0 points.

A 47-point function scale was completed for each person. Gait quality was assigned up to 33 points: 11 points for no limp, 8 points for a mild limp, 5 points for a moderate limp, and 0 points for a severe limp; 11 points for no need for auxiliary support, 7 points for need of a cane for long-distance walking, 5 points for need of a cane most of the time, 3 points for need of a single stick, 2 points for need of a stick in both hands, and 0 points for need of crutches or a total inability to walk; and 11 points for ability to walk an unlimited distance, 8 points for the ability to walk six blocks (600

m), 5 points for the ability to walk about 2-3 blocks (200-300 m), 2 points for walking indoors only, and 0 points for the inability to walk any distance (staying in bed or a wheelchair). Daily activities were assigned the remaining 14 points: 4 points for the ability to climb up and down stairs normally, 4 points for climbing up and down stairs normally and without needing a handrail, 2 points for needing armrest handrail, 1 point for needing auxiliary support to climb down the stairs, and 0 points for total inability to climb up and down stairs; 4 points for ease in wearing shoes and socks, 2 points for some difficulty in wearing shoes and socks, and 0 points for total inability to wear shoes and socks; 5 points for no discomfort when sitting in an ordinary chair for one hour, 3 points for no discomfort when sitting in a high chair for half an hour, and 0 points for discomfort in any chair; and 1 point for being able to use public transport.

For deformity, we assessed patients on a 4-point scale: 1 point for fixed flexion contracture < 30°, 1 point for fixed adduction deformity < 10°, 1 point for straight fixed rotation deformity < 10°, and 1 point for difference in limb length on both sides of < 3.2 cm.

We also assessed range of motion on a 5-point scale according to flexion, adduction, abduction, internal rotation, and external rotation angles: 5 points for 300°-210°; 4 points for 209°-160°; 3 points for 159°-100°; 2 points for 99°-60°; 1 point for 59°-30°; and 0 points for 29°-0°.

These scores were totaled. Together, they comprised a 100-point scale for functioning assessment. Scores of 90-100 were considered excellent; 80-89, good; 70-79, moderate; and ≤ 70, poor, as proposed by Harris in 1969 [12].

Surgery

An experienced deputy director performed all surgeries using the lateral approach. For the LHA group, a Pinnacle acetabular cup and Corail stem prosthesis (Depuy, United States) were used. For the SHA group, an Option acetabular cup and Corail stem prosthesis (Depuy, USA) were used. Both are biological fixation prostheses. Partial weight bearing was performed 24 hours after surgery, and full weight bearing was performed 4 weeks after surgery.

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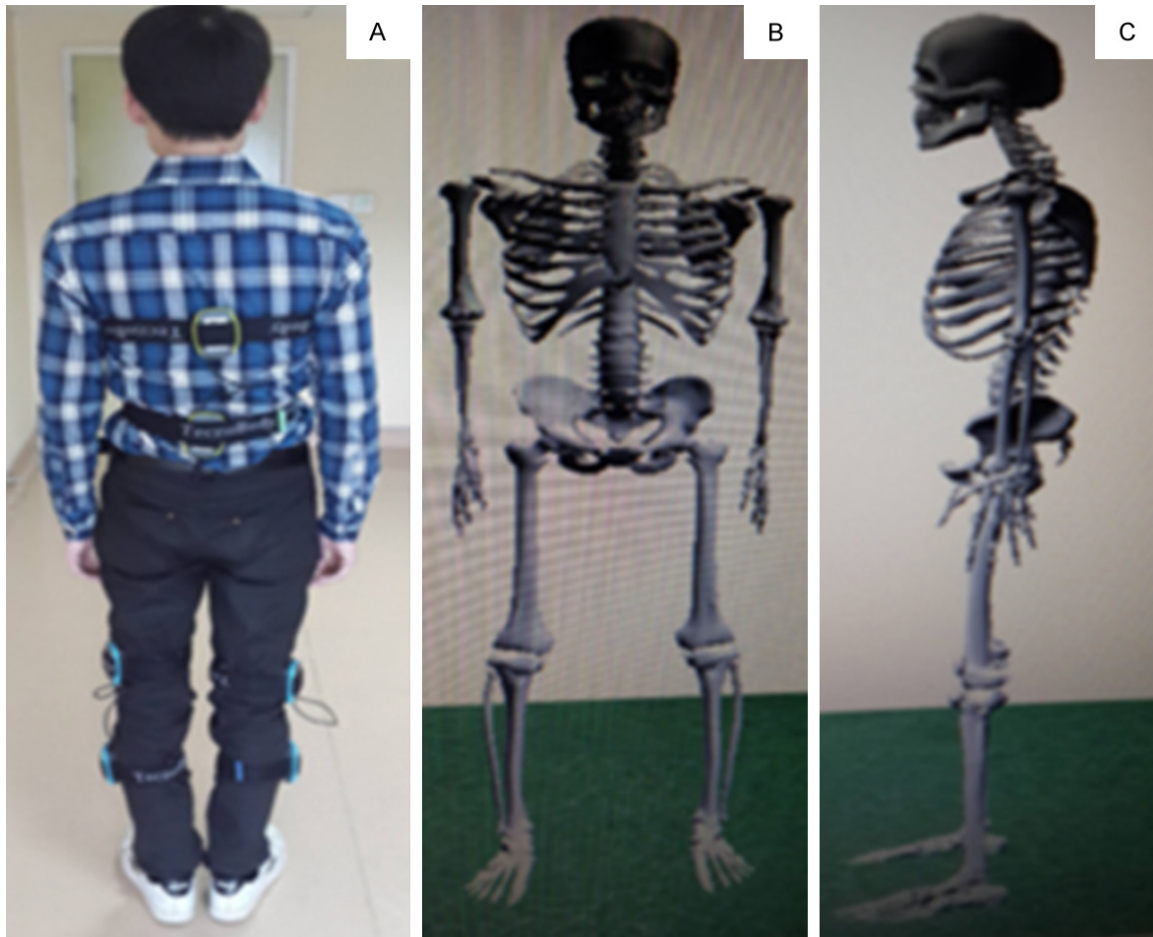


Figure 1. After being fixed six modules based on dissection marks, the detected patients walked on trails in accordance with everyday walking pattern (A); Tecnobody three-dimensional motion analysis system was used to reconstructed the three-dimensional gait model of the detected patients (B, C).

Postoperative follow-up

Follow-up was conducted at 3 months, 6 months, and 1 year after surgery. Images of the anteroposterior pelvis and affected lateral hip were taken to exclude patients with improper placement of the prosthesis and prosthesis loosening, subsidence, dislocation, ectopic bone, or other complications. One year after surgery, hip function was assessed using the Harris score and gait analysis was performed using the Italian Tecnobody three-dimensional gait analyzer.

Gait analysis

The Tecnobody three-dimensional motion analysis system (Tecnobody, Italy) was used to measure gait parameters. Before gait analysis, body parameters (height, weight, femur length,

tibia length, and foot length) were measured. The Tecnobody patient motion analysis system includes a wireless inertial sensor network. This new technology offers completely free movement without a camera, but with accelerometers, gyroscopes, and inertial magnetic sensors, which can detect all angular motion inside a biomechanical structure in real time. The detailed analysis was as follows: we fixed six modules to the body and lower limbs of the patients based on anatomical landmarks. Of these modules, two were grouped; the two modules for the body sensor were fixed to the subscapular area and the upper edge of the iliac crest. The modules for both lower limbs were fixed to one-third of the outside of the lower thighs and one-third of the inside of the upper legs (**Figure 1A**). Then we opened the module switches, connected computer software via Bluetooth, and after a successful con-

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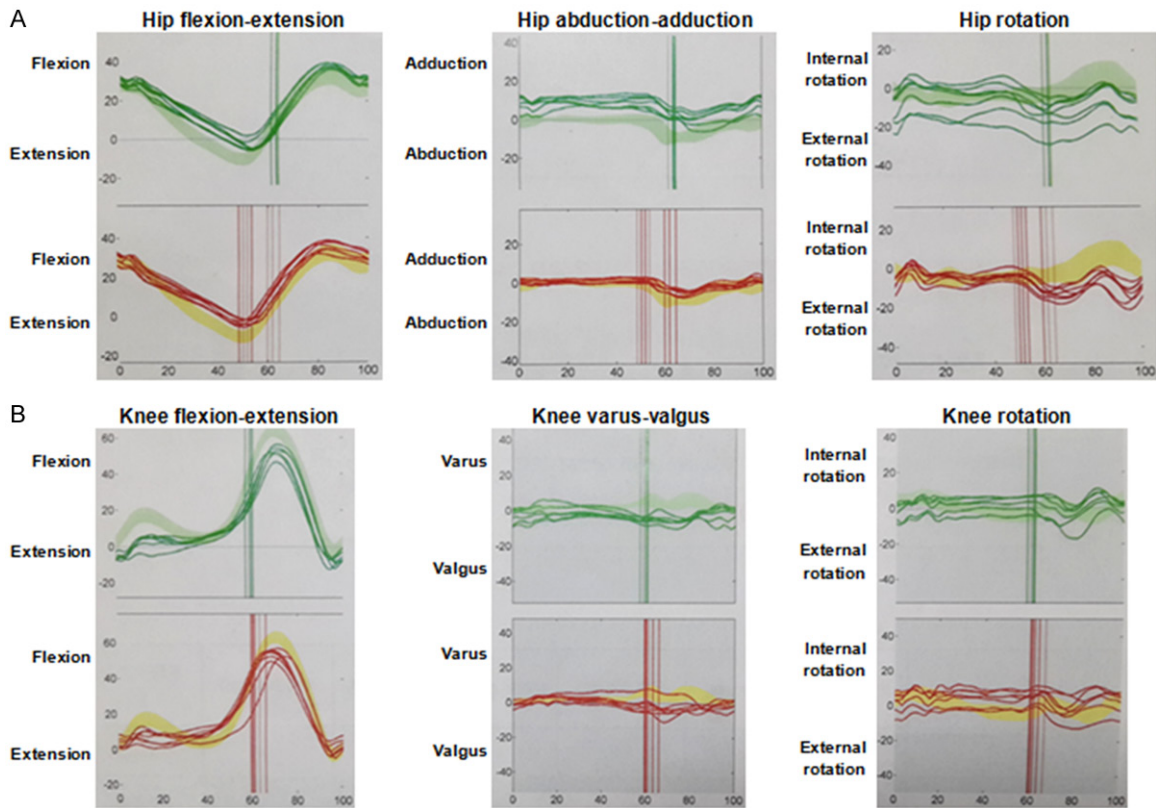


Figure 2. Changes graph of hip (A) and knee (B) motion in gait cycle (horizontal axis was the corresponding phase in gait cycle, the vertical axis was the degree of hip and knee motion. Red curve represented the left leg, green indicated right leg curve. Flexion degree was positive, stretching degree was negative).

nection, entered the gait analysis section. After completing this section and setting the device back to zero, we asked the patient to walk a seven-meter walking trail in the typical manner of their daily life. The resulting data were entered into a computer, and gait analysis software of the TecnoBody motion analysis system was used for data processing to obtain gait analysis results (**Figure 1B** and **1C**). Each test was completed by the same team of experienced doctors from the rehabilitation department.

Outcome measures

Outcome measures included step cadence (step/min), step time (s), step length (cm), walking speed (m/s), the proportion of the gait cycle accounted for by the single leg support phase, (6) the proportion of the gait cycle accounted for by the single-leg swing phase, and hip and knee motion (**Figure 2**).

Statistical analysis

The seven data points above were used to calculate the ipsilateral/contralateral ratio for

each patient. This ratio and the Harris score were subjected to statistical analysis using the SPSS13.0 statistical software package (Chicago, IL, USA). The two groups were compared using two independent sample t-tests for statistical analysis. $P < 0.05$ was considered statistically significant.

Results

Imaging

Two groups of patients did not complain of any obvious discomfort. Radiographic examinations showed good prosthesis positioning. No prosthesis loosening, dislocation, subsidence, or other complications occurred (**Figure 3**). There were no cases of abnormal sounds, infection, deep venous thrombosis, nerve injury, or other complications.

The Harris score

The comparison of postoperative Harris scores for patients in the two groups is shown in **Table 1**. The mean score was better in the LHA group

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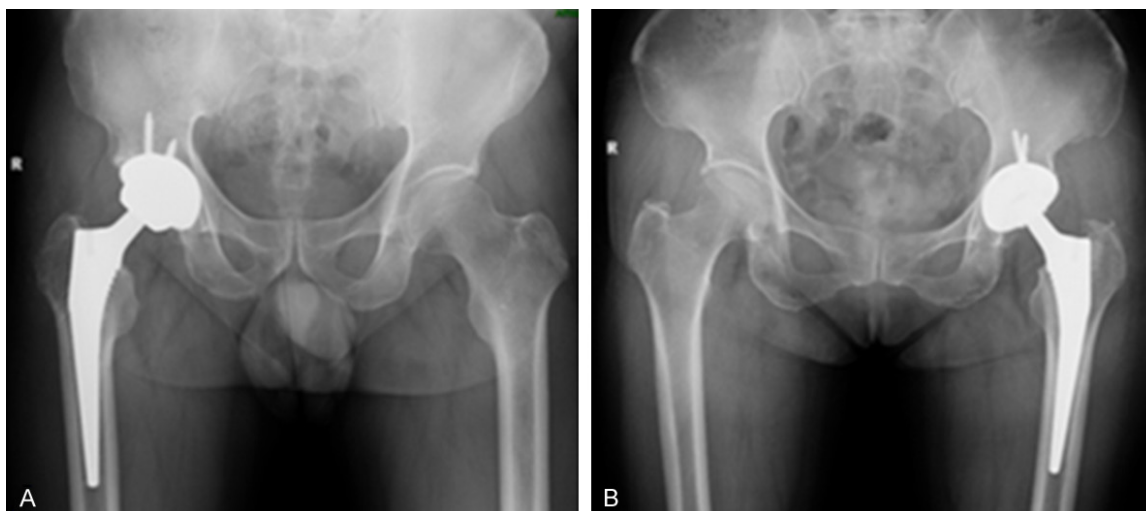


Figure 3. A: Male, 55 years old, right avascular necrosis. 1-year hip anteroposterior X-ray of 36 mm large-diameter femoral total hip arthroplasty showed that the prosthesis had a good location without loosening and dislocation; B: 64 years old, left femoral neck fracture. 1-year hip anteroposterior X-ray of 28 mm large-diameter femoral total hip arthroplasty showed that the prosthesis had a good location without loosening and dislocation.

Table 1. Age and preoperative and postoperative Harris score of patients in the two group

Group	Male/ Female	Age (years)	Preoperative score (points)	Postoperative score (points)
36 mm	13/17	52.8±9.1	41.6±12.4	91.0±5.8
28 mm	11/19	55.5±7.9	42.8±13.1	89.8±6.1
T value		0.58	0.48	0.56
P value		0.63	0.82	0.76

(91.0±5.8) than in the SHA group (89.8±6.1), but the difference was not statistically significant.

Gait

The ipsilateral/contralateral ratios of patients in the two groups are shown in **Table 2**. The ratios for step cadence, step time, proportion of the gait cycle accounted for by the single-leg stance phase, and proportion of the gait cycle accounted for by the single-leg swing phase were 0.9985, 1.0032, 1.0028, and 1.0052, respectively, for the LHA group, and 0.9972, 1.0051, 0.9987, and 1.0037, respectively, for the SHA group. The *P*-values of the intergroup comparisons were 0.915, 0.891, 0.362, and 0.902, respectively. These differences were not significant, and the four gait parameters were similar for the ipsilateral and contralateral sides. The ipsilateral/contralateral ratio for step length and pace were 0.9981 and 0.9939, respectively, for the LHA group, and 0.7932 and

0.8116, respectively, for the SHA group. The *P*-values for the intergroup comparisons were 0.005 and 0.031, respectively, indicating statistical significance. The ipsilateral/contralateral ratios for hip and knee motion in a gait cycle in the two groups are shown in **Table 3**. The ipsilateral/contralateral hip flexion/extension, adduction/abduction, and rotation ratios in the gait cycle were 1.0042, 0.9847, and 0.9963, respectively in the LHA group, which were significantly higher than those in the SHA group (0.8592, 0.7917, and 0.7853, respectively). The *P*-values for the differences were 0.008, 0.005, and 0.006, respectively, indicating a statistical significance. Knee motion was also better in the LHA group than in the SHA group: the ipsilateral/contralateral flexion/extension ratio was 1.0912 in the LHA group and 0.9173 in the SHA group. The *P*-values for the difference was 0.035, indicating statistical significance. The adduction/abduction and rotation of the ipsilateral knee was similar to that of the contralateral knee, and the difference between the two groups was not statistically significant.

Discussion

Various methods are in use for post-surgical assessments of artificial hip replacements. Gait analysis is one of the more objective approaches. With the rapid development of computer technology over the past 20 years,

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Table 2. Comparison of gait parameters ratio (ipsilateral/contralateral) of patients in the two groups

Group	Step cadence	Step time	Step length	Pace	Percentage of single-leg support phase accounted the gait cycle	Percentage of single-leg swing phase accounted the gait cycle
36 mm	0.9985±0.0279	1.0032±0.0356	0.9981±0.0548	0.9939±0.0337	1.0028±0.0491	1.0052±0.0583
28 mm	0.9972±0.0316	1.0051±0.0415	0.7932±0.2132	0.8116±0.1519	0.9987±0.0256	1.0037±0.0536
T value	0.109	0.133	2.872	2.158	0.852	0.118
P value	0.915	0.891	0.005	0.031	0.362	0.902

Table 3. Comparison of hip and knee motion ratio (ipsilateral/contralateral) of patients in the two groups

Group	Hip flexion	Hip extension	Hip rotation	Knee flexion/extension	Knee adduction/abduction	Knee rotation
36 mm	1.0042±0.2294	0.9847±0.2837	0.9963±0.3945	1.0912±0.1247	1.0239±0.6865	1.0132±0.4992
28 mm	0.8592±0.2146	0.7917±0.2108	0.7853±0.2079	0.9173±0.1012	0.9965±0.5202	0.9818±0.3751
T value	2.795	2.897	2.835	2.132	0.423	0.877
P value	0.008	0.005	0.006	0.035	0.655	0.319

gait analysis technology is booming. It is now more widely applied to evaluate the efficacy of hip replacement surgery. It is also used more widely used to quantitatively evaluate function by collecting data such as body kinematics, body dynamics, and dynamic electromyography data. This allows the comparison of the impact of factors such as different surgical replacements and surgical approaches, and thus provides a basis for the selection of surgical prostheses and rehabilitation programs [6, 7, 13]. With the continuous development of biomechanics and information processing technology, the functioning of the new gait analysis system is improving, and gait analysis has played an increasingly important role in evaluating hip arthroplasty success. We used a TecnoBody three-dimensional gait analysis system from Italy, which adopted advanced Bluetooth receiver technology to collect data. This system has advantages such as high accuracy over gait analyzers that use optical or electromagnetic data collection systems, low environmental interference, ease and swiftness of operation, dynamic data detection and recording, availability for use with a video of walking, direct comparison of bilateral differences in limb motion, and ability to understand the joint activity curve.

Many studies have reported the effect of gait after total hip replacement surgery on hip function, degree of wear and tear, prosthesis retention rate, complications, and other aspects. Based on postoperative gait analysis after total

hip arthroplasty with an ultra-high molecular weight polyethylene acetabular component, Davey et al. found that postoperative gait was an important factor in influencing ultra-high molecular weight polyethylene acetabular prosthesis and long-term biocompatible efficacy [14]. Foucher et al. evaluated the efficacy of total hip replacement surgery for 28 patients within a year of surgery and found that the improvement in postoperative gait was of great value in increasing the load capacity of the hip and reducing the risk of prosthesis loosening [15]. Zhou et al. analyzed the influence of a metal-on-metal large-diameter-femoral head prosthesis (40-49 mm) and a metal-on-polyethylene standard-diameter femoral head prosthesis (28 mm) on postoperative gait, and found that patients with the large-diameter-femoral head prostheses showed better recovery within 3 months after surgery [9]. Lavigne et al. reported that gait parameters after metal-on-metal large-diameter-femoral head total hip replacement were superior to those after standard-diameter-femoral head total hip replacement [10].

The ceramic-ceramic combination is currently the most promising friction interface. Due to its low wear rate and inert particles, ceramic-on-ceramic hip prostheses have had a large number of clinical applications in recent years, especially since the increasing use of large-diameter ceramic heads in young patients and patients with high levels of activity [16]. However, there are no studies on gait analysis

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for objective comparisons of postoperative functioning of ceramic-ceramic large-diameter femoral head and standard-diameter-femoral head total hip arthroplasty. A 1-year postoperative gait analysis in patients who had undergone the two total hip replacement surgeries showed no significant differences in step cadence, step time, proportion of the gait cycle accounted for by the single-leg support phase, and proportion of the gait cycle accounted for by the single-leg swing phase between the two groups. These values were similar to those of the normal contralateral side (i.e., the ipsilateral/contralateral ratio was close to 1). The postoperative Harris score did not differ significantly between the two groups. However, step length, pace, hip motion, and knee motion were significantly better in the LHA patients than in the SHA patients and were similar to values on the normal contralateral side in the LHA group. Davis et al. concluded that ipsilateral hip motion was an important factor that impacted ipsilateral limb function after hip replacement surgery and that there was a positive correlation between the two [17]. A wide range of motion allowed the support and swing phase of the replaced hip in the gait cycle to have better flexion and internal rotation, thereby improving walking speed (pace), extending stride distance (step length), and returning activity to normal levels. The study confirmed Davis' view by employing an objective evaluation tool.

Compared with the traditional standard-diameter femoral head total hip replacement, large-diameter femoral head total hip replacement can reduce the incidence of dislocation and increase joint stability by increasing the "dislocation distance" (the distance between the highest point of the prosthesis-headed surface and the acetabulum edge) [18, 19], and can increase joint activity by extending the distance of the prosthesis neck and the edge of the acetabular cup [20, 21]. In this study, the postoperative ipsilateral gait parameters and hip and knee motion of the patients in the LHA group approached the normal contralateral levels. The Harris score was high, indicating that the design of ceramic-ceramic large-diameter femoral head prosthesis can be relatively more effective in restoring joint function in patients compared with the standard-diameter femoral head prosthesis.

Abnormal sounds were noted as a common complication of ceramic-ceramic friction.

Abnormal noise has drawn increasing attention from clinicians and patients. However, this is not unique to the ceramic-ceramic friction interface and also occurs in cases of hard-on-hard friction interfaces, such as the metal-on-metal friction interface [22]. The reported incidence of abnormal sound varies from < 1% to 20.9% [23]. A meta-analysis of the abnormal sound for the third-generation and fourth-generation ceramic prosthesis by Stanat et al. showed that the incidence of abnormal sound among 6137 patients was 2.4% [24]. Abnormal sound was not normally associated with pain, discomfort, or dysfunction, so most patients can tolerate it. Cases of reoperation due to intolerable abnormal sound have also been reported [25]. Many studies have reported the reasons for abnormal sound, including edge hit, microdissection or subluxation, bar wear, a vertical acetabulum increasing the force on the edge, use of a short-necked prosthesis, and surrounding soft tissue relaxation. Some studies have also reported that the abnormal noise did not primarily originate in the ceramic itself, but resulted from its matched prosthetic design [26]. Currently, the abnormal sound of the hip joint after total hip arthroplasty is caused by multiple factors, including those related to the patient, surgical technique, and prosthetic material and design. Abnormal friction of the interface produced by multiple factors results in prosthesis vibration, which results in abnormal sounds. In this study, the patients in the two groups did not experience abnormal sound. This may be because the choice of the implant prosthesis design was reasonable or because surgical technical factors such as improper placement of the prosthesis and leg length discrepancy were excluded.

In this study, the ipsilateral/contralateral gait parameter ratios of patients in the two groups were used for statistical analysis. This can be used to observe whether ipsilateral gait parameters were similar to the contralateral levels. However, it can also be used to reduce the impact of factors such as sex, age, and weight on the results. This made the analysis results more accurate and reliable.

The limitations of this study were that data on preoperative gait were lacking. In the follow-up study, we used a forward-looking design to perform preoperative and postoperative gait comparisons, which may have been more objective and an accurate reflection of the postoperative

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joint function recovery effect. Furthermore, the postoperative follow-up time was only about 1 year, and thus, evaluation of the moderate- and long-term results will require further follow-up.

Conclusion

One year after surgery, gait parameters and joint range of motion were superior in patients who underwent LHA compared to those who underwent SHA. A large-diameter-femoral-head prosthesis may be more effective in the recovery of joint function in patients after surgery, which provided a theoretical basis for the selection of prosthesis in surgery. Good prosthesis selection can improve gait after total hip arthroplasty, reduce prosthesis loosening rate, lower revision rate, reduce medical costs and patients' pain.

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Disclosure of conflict of interest

None.

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