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ORIGINAL PAPER

Function and activity after minimally invasive total hip arthroplasty compared to a healthy population

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Abstract
Purpose The aim of the present study was to compare the daily activity and functionality in a patient cohort 12 months after total hip arthroplasty (THA) using a direct anterior approach with a healthy non-operated control population.
Methods Sixty-four patients who underwent THA and 59 healthy individuals (control) were assessed regarding their daily activity and joint functionality utilizing the Harris hip score (HHS), the extra short musculoskeletal functional assessment questionnaire (XSFMA), the Short Form 36 (SF-36) health survey and a Stepwatch™ Activity Monitor (SAM). Post-operative x-ray images after THA were analysed regarding inclination and stem positioning.
Results Twelve months after surgery, the average HHS showed no significant difference between both groups equalling 90.7 points in the THA patient group and 90.8 in the healthy volunteer group. The XSFMA functional index scores were 11.0 (THA) and 5.0 (control) while the bother index summed up to a score of 15.3 (THA) and 7.6 (control) respectively thus differing significantly ($p < 0.001$). Daily activity equalled 4227 (THA) and 4687 (control) load cycles per day ($p = 0.327$) while a number of 5658 (THA) and 6417 (control) steps per day ($p = 0.011$) was recorded.

The SF-36 physical component scores were 47.3 (THA) and 50.6 (control) points while the psychometric properties added up to a score of 56.1 (THA) and 55.9 (control). The physical component was determined to be significantly different ($p < 0.001$) whereas no statistically significant difference could be shown for the psychometric properties ($p = 0.511$).

The radiographic analysis revealed an average cup inclination of 39.9° without signs of migration. Stem positioning was neutral in 53% of all cases while 36% were graded varus and 11% valgus.
Conclusion In summary, our short-term results show an activity, functionality and quality of life for patients one year after THA comparable to healthy control individuals.

Keywords Total hip arthroplasty · Minimally invasive · Direct anterior approach · Outcome · Healthy population

Introduction

Total hip arthroplasty (THA) represents one of the most successful procedures in orthopaedic surgery [1–3]. Especially, the rate of minimally invasive surgery (MIS) is continuously increasing. The relief of pain, restoration of functionality and activity notably improving the patients' quality of life give rise to an increasing demand for hip replacement surgery [2]. Annually, about 230,000 THAs are performed in Germany and the rate of minimally invasive surgeries (MIS) is continuously growing. In the majority of cases the direct anterior, the anterolateral and the posterior approaches to the hip are used during MIS [4].

Recent literature commonly compares different MIS approaches for THA with respect to the duration of hospitalization, blood loss, pain levels and the achieved functional outcome [5].

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In contrast, we prospectively compared the functional outcome and daily activity of patients after THA — performed via a minimally invasive, single-incision direct anterior approach — with a healthy control population.

Materials and methods

Between January 2009 and January 2010 64 patients undergoing unilateral total hip arthroplasty via a minimally invasive direct anterior approach and 59 healthy individuals without any signs of osteoarthritis (controls) were included in this prospective study (Table 1) [4]. The controls were selected from 400 randomly chosen individuals as provided by the local registry office. The study was approved by the institutional ethics committee of the University of Würzburg.

Inclusion criteria for both groups were an age between 40 and 80 years, the patients in the THA group had to be diagnosed with primary osteoarthritis of one hip, whereas the healthy controls were required to show no signs of osteoarthritis as assessed by medical history and clinical examination.

Exclusion criteria for both groups were past fractures of the lower limb, combined osteoarthritis of both the hip and the knee, hip dysplasia, osteoporosis, past osteotomies of the hip or femur, chronic lower back pain and a BMI > 35 kg/qm^2. Furthermore, control individuals were precluded to suffer from peripheral arterial obstructive disease or general discomfort of the lower limb.

The subjects enrolled in the THA group received Trilogy cups (Trilogy® Acetabular Hip System, Zimmer) combined with a non-cemented stem (M/L-Taper, Zweymüller® Alloclassic®, Mayo®, all Zimmer) or cemented M. E. Müller straight stem (Zimmer). All devices used are commercially available and were implanted according to approved labelling. The surgeries were performed by four fellowship-trained surgeons with extensive experience in the applied technique.

Patients were examined six weeks prior to surgery and six weeks, three, six and 12 months post surgery. In contrast, healthy controls were subject to a single clinical examination.

Hip function was evaluated using the Harris hip score (HHS) [6] and the reciprocal extra short musculoskeletal functional assessment questionnaire (XSMFA functional and bothering Index) [7].

The activity was evaluated using the daily activity questionnaire (DAQ) [3] and the Stepwatch™ Activity Monitor (SAM) (Orthocare Innovations, Oklahoma City, OK, USA) over a period of seven days.

The individual patient health status was monitored using the short-form 36 questionnaire (SF-36 mental and physical) [8].

Conventional anterior-posterior pelvis and cross-table lateral radiographic projections (frog leg view) were obtained to assess skeletal fixation, cup position (inclination), and stem orientation (neutral, valgus or varus) as described previously [9].

For statistical analysis the two-tailed Mann-Whitney U test (SPSS 19.0, IBM Inc.) was applied and p-values <0.05 were considered significant.

Table 1 Characteristics of THA patients and healthy controls

	THA	Control
number of patients (n)	64	59
age (years)	63.0	64.3
female (n)	30	31
male (n)	34	28
body mass index (BMI)	27.1	26.0

Results

The average HHS score showed no significant difference 12 months after THA (90.7 ± 10.6 out of 100 points) when compared to the healthy control group (90.8 ± 1.8). Compared to the pre-operative score of 61.5 ± 10.7 the scores 6 weeks (80.5 ± 12.8), 3 (87.4 ± 8.7) and 6 (92.2 ± 10.1) months after THA increased significantly ($p < 0.05$) (Fig. 1 and Table 2).

The average functional index of the XSFMA was calculated to be 11.0 ± 11.6 12 months after THA and 5.0 ± 10.8 for healthy controls respectively. In contrast to the pre-operative score (32.2 ± 14.2) the functional index decreased significantly over the evaluation period from 22.0 ± 16.2 (6 weeks), 13.6 ± 10.4 (3 months) to 11.8 ± 12.5 (6 months). On the other hand, the pre-operative bother index equalled 44.9 ± 17.6 and improved from 27.9 ± 18.6 (6 weeks), over 20.7 ± 14.8 (3 months), and 17.9 ± 15.9 (6 months) to 15.3 ± 15.3 (12 months). For the control group the bother index was calculated to be 7.6 ± 14.1. Statistically, both outcomes of measurement differed significantly ($p < 0.001$; Fig. 1 and Table 2).

On the contrary, the average number of load cycles per day determined 12 months after THA (DAQ; 4226 ± 948) and for healthy controls (4686 ± 400) did not differ significantly ($p = 0.327$). Compared to the pre-operative values (3727 ± 947), a significant increase was seen after six months (4070 ± 1728) ($p < 0.01$) following an initial decrease six weeks (3203 ± 957) and three months (3546 ± 1263) post-operatively (Fig. 2 and Table 2).

The SAM results showed a significant difference in regard to the number of steps per day recorded for the THA group at 12 months (5658 ± 2213) compared to controls (6417 ± 2213) ($p = 0.011$). Compared to the pre-operative values (5541 ± 2048), no significant increase was seen over the evaluation period (Fig. 2 and Table 2).

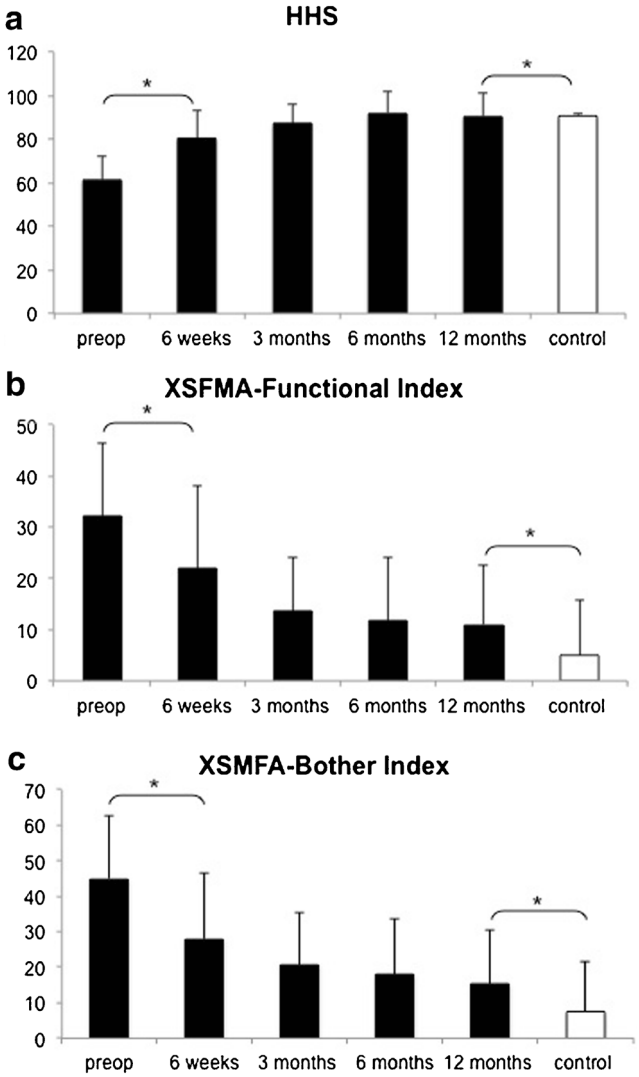

Fig. 1 Study results obtained for the Harris hip score (HHS) and XSFMA compared to the control group. Values are presented as mean ± standard deviation

The average scores obtained in the physical component of the SF-36 were calculated to be 45.8 ± 9.3 one year after THA and 50.7 ± 9.3 for the control group thus of statistically significant difference ($p < 0.001$). On the other hand the psychometric properties summed up to a score of 56.1 ± 7.4 12 months after THA and 55.9 ± 6.9 for controls ($p = 0.511$). Compared to the pre-operative scores (28.7 ± 9.5 physical and 57.9 ± 8.9 psychometric), a significant increase was seen for the physical component but not for the psychometric component post-operatively (Fig. 2 and Table 2).

Table 2 Study outcome in regard to functionality, daily activity, pain level and quality of life

	THA	Control	*p*-value
HHS (points)	90.7	90.8	>0.05 n.s
DAQ (load cycles)	4227	4687	0.327 n.s.
Stepwatch (step/day)	5658	6417	0.011
F-XSFMA (points)	11.0	5.0	<0.001
B-XSFMA (points)	15.3	7.6	<0.001
SF-36 mcs (points)	56.1	55.9	0.511 n.s
Sf-36 pcs (points)	47.3	50.6	<0.001
pain (VAS)	1.311	0.0	

Average pain intensity measurements one year after surgery equalled 1.31 (THA) compared to 5.8 pre-operatively while a score of 0.0 was determined for healthy controls.

The radiographic analysis after THA revealed an average cup inclination of 39.9° (± 8.3°). None of the cups presented evidence of migration one year after surgery. Stem positioning was assessed as neutral in 53% of all cases while 36% were graded varus and 11% valgus. In case of non-cemented THA, all components showed radiographic signs of osteointegration such as bone in- and bone on-growth (Table 3).

Peri- and post-operative complications associated with arthroplasty through the direct anterior approach included five cases of persistent lateral femoral cutaneous nerve affection 12 months after surgery, which appeared not to affect outcome scores, and a leg length discrepancy of one centimetre or less in 11 cases, two of which were addressed with orthopaedic insoles due to clinical relevance.

Discussion

The numbers of minimally invasive hip arthroplasties performed are continuously increasing. Literature suggests a decreased intra-operative blood loss, lower post-operative pain levels and a shorter recovery time [1–3] when minimally invasive approaches are used for total hip arthroplasty. The functional mid-term outcomes achieved applying these minimally invasive techniques were reported to be equal to the clinical outcomes observed after THA via standard approaches [3].

None of the above-mentioned studies, however, ever related the functional outcome after THA to a healthy control population.

Our prospective study examining 64 patients one year after THA also involving 59 healthy control individuals shows comparable outcomes of the anterior approach group and the control group as evaluated by the HHS, XSFMA, DAQ, SAM and the SF-36. The results obtained in the THA patient group are within the expected range and similar to those reported in previous studies [5].

The results gained using the Stepwatch™ Activity Monitor, an objective method of taking measurement, differed significantly between both study groups with an average of 5658 (THA) and 6417 (control) steps/day respectively. On the contrary, the DAQ results for both groups did not differ significantly with 4227 (THA) and 4687 (control) load cycles. It

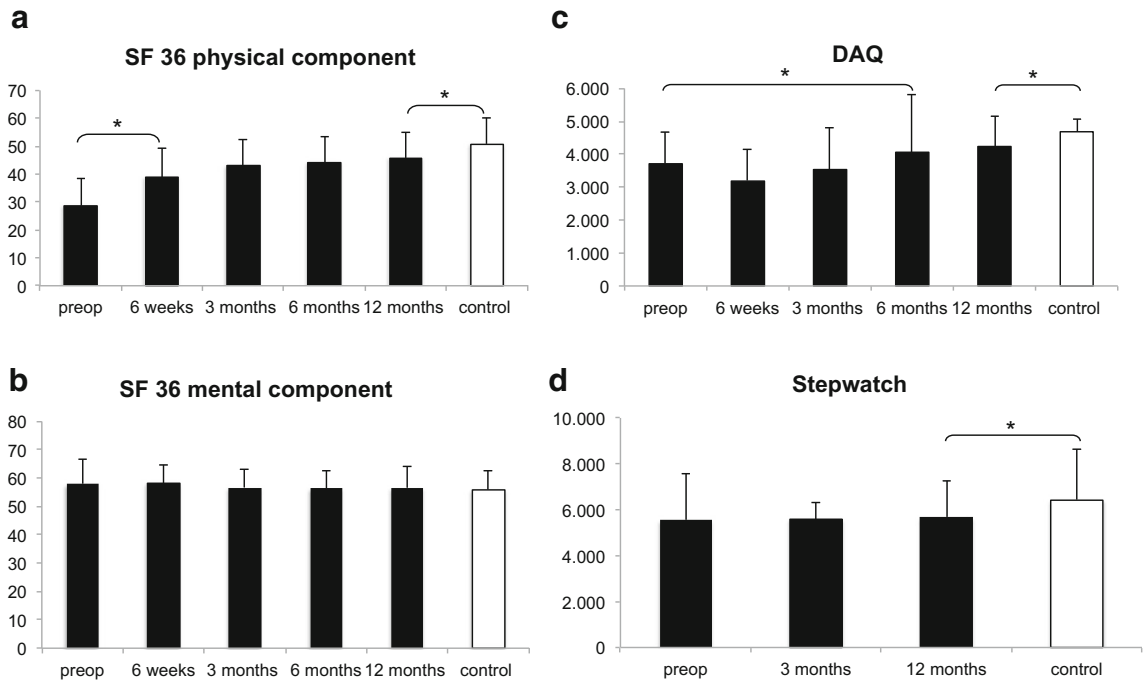

Fig. 2 Scores achieved for the SF-36 mental (MCS) and physical component (PCS), the daily activity questionnaire, and Stepwatch Activity Monitor compared to healthy control individuals. Values are presented as mean ± standard deviation

is, however, difficult to compare these results with the outcomes published in previous studies since different devices were applied to record patient activity, such as mechanical pedometers or traditional accelerometer- based step counting modalities, with varying periods of patient observation [10]. Wollmerstedt et al. for example depicted 6500 steps/day while Naal et al. described 7000 steps/day five years after THA [11, 12]. However, Naal et al. described an increase of the daily activity over the first five years after THA [12]. In our study a similar level of activity was already obtained after the first year. The results shown by Kinkel et al. and Silva et al. reported comparable data with 6144 and 5737 steps/day respectively [13, 14].

A possible explanation for these observed variations could be a restriction of patient activity due to existing co-morbidities [15]. Changes in walking pace as well as a changed postural control/gait pattern could possibly be another reason [16]. The DAQ measured no significant difference of activity for both the THA and control groups.

Similarly, functionality as represented by the Harris hip score did not reveal a significant difference while obtained XSMFA scores differed significantly. Generally, our outcomes correspond with previous literature reports about minimal-invasive hip replacement although we obtained higher XSMFA scores [17, 18]. The difference in outcomes comparing the HHS and XSMFA could be attributed to their different weightings. The HHS is subdivided in pain, functionality and deformities. In contrary the XSMFA is subdivided just in functionality and bother index. The results show nearly equal functionality for both groups but the individuals of the THA group still feel more discomfort one year after THA. This is also reflected in the results of the SF-36 physical component score.

The results of our study depict that even an age-matched healthy control population cannot achieve maximum scores when assessing activity and functionality, which is in line with Sander et al. [19]. Consequently, it is rather recommended to relate activity and functionality scores after joint replacement to values achieved by a healthy control group than to the possible top scores of the respective test tool.

In both collectives the SF-36 did not show any differences for the mental part. However, after a one-year period, a significant difference could still be observed for the physical component proofing that patients have not fully recovered one year after total hip arthroplasty. Reichert

Table 3 Radiographic analysis of cup and stem positioning; surgery-related complications

	THA
inclination	39.9 (28.1–50.7)
stem positioning	normal 33
	varus 23
	valgus 7
exchange of parts	0
femoral nerve paresis	0
ischiadic nerve paresis	0
lateral femoral cutaneous nerve paraesthesia	5 (7.8%)

et al. reported that this phenomenon was no more evident five years after THA [5].

MRI based assessment of muscular degeneration and trauma in minimally invasive hip replacement surgery using a direct anterior approach showed a certain degree of muscular atrophy and fatty infiltration even preoperatively. Six months after surgery a significant decrease of the cross sectional area indicative of atrophic changes and a significantly increased fatty infiltration was detected for the M. tensor fasciae latae and the *M. glutaeus* minimus, whereas no changes were determined for the *M. glutaeus* medius [20].

The results indicate that an increasing number of daily steps correlates well with physical health whereas a higher activity level does not necessarily affect mental health. Similar observations have already been published by Khan et al. and Wollmerstedt et al. irrespective of the approach used for THA [21, 22].

Post-operative radiographic analysis revealed an average inclination of 39.9° ± 8.3°, which is comparable to previous reports [4, 23, 24].

Nakamura et al. described an average inclination of 45.7° using the minimal-invasive posterior and an average of 44.8° applying the direct lateral approach [25].

Radiographic analysis of stem positioning showed a high incidence of varus positions. This may be attributed to the direct anterior approach which generally tends to force stem placement into a varus position. In the past, similar results were also obtained by Rachbauer et al. and Oinuma et al. [4, 24].

To avoid varus positioning, the femoral canal must be entered as laterally as possible.

Our study has several limitations. It is a non-randomized, un-blinded prospective study, which could lead to potential bias. In addition, the possibility of an inadequate sample size should be considered. Nevertheless, in our study, we included a considerably large sample size that may have prevented the before mentioned potential statistical errors. Another limitation might be the strict exclusion criteria. These could have influenced the results of both the experimental and control group.

Despite the above-mentioned limitations, our results conclude that the minimally invasive direct anterior approach leads to similar clinical short-term outcomes when compared to a healthy control population.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval The study was approved by the ethics committee of the University of Würzburg.

Informed consent Informed consent was obtained from all individual participants included in the study.

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