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Anterolateral Minimally Invasive Total Hip Arthroplasty

A Prospective Randomized Controlled Study With a Follow-Up of 1 Year

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Abstract: Anterolateral minimally invasive hip surgery (ALMIS) is a challenging procedure that is thought to offer a more expedient and a better functional outcome. Seventy-nine patients receiving primary hip arthroplasty were randomized. Röttinger ALMIS technique was used for 42 patients, whereas 41 received the standard lateral transgluteal Hardinge approach. Operative time was longer with ALMIS (P = .000078), whereas blood loss was less (P = .008). Surgical and postoperative complication rates, morphine consumption, and length and cost of hospitalization were similar. At 1 year, Harris, Postel and Merle d'Aubigné, and Short Form–36v1 scores were similar. Gait analysis revealed similar results. Computed tomographic analysis revealed no significant difference in implant position, heterotopic ossification, and loosening. Röttinger ALMIS is a valid approach for hip arthroplasty. However, it offers no advantages at 1 year. **Keywords:** anterolateral minimally invasive hip arthroplasty, Röttinger minimally invasive approach, randomized controlled study, gait analysis, CT scan, costs.

Over the last 40 years, total hip arthroplasty (THA) has been a highly successful operation, with documented benefits of significant reduction in pain and improvement in quality of life. In the last decade, minimally invasive hip surgery (MIS) has been growing in popularity both in public perception and in the orthopedic community. Presumed MIS short-term benefits are less blood loss, decreased pain, and a smaller incision, whereas hypothesized long-term benefits include preserved gait characteristics, lower dislocation rates, and more consistent pain relief. However, it remains a subject of controversy, as MIS is thought to be at higher risk of implant malalignment without significant functional benefit.

Many techniques and approaches have been described in the literature [1]. The MIS approach described by Bertin and Röttinger [2] in 2004 is often chosen by surgeons who are familiar with the lateral Hardinge approach. This approach comes closest in regards to patient position and anatomical landmarks aiding in transition between the two. The Röttinger approach uses the intermuscular interval between gluteus medius and tensor fascia lata and avoids detachment of muscles from their insertion.

Despite the proposed benefits of MIS THA, the literature is deficient in well-designed studies to support its clinical superiority over traditional THA. In fact, a search in PubMed with the terms *minimally invasive*, *hip*, and *arthroplasty* since 1999 identified only 14 randomized control trials (RCTs). These studies involved, for the most part (9/14), the MIS posterior approach; assessed short-term results; and presented conflicting data. Only 2 RCTs [3,4] were identified with the anterolateral minimally invasive hip surgery (ALMIS) approach as described by Röttinger. These studies had small sample sizes (n = 20), insufficient follow-up (6 weeks [3] and 3 months [4]), and limited criteria of evaluation. The objective of this randomized prospective study is to determine if the Röttinger ALMIS approach offers any clinical advantage to the standard Hardinge approach at 1 year.

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Materials and Methods

Patients' Inclusion

All patient procedures and follow-up were conducted at the Grand Hospital in Charleroi, Belgium. Ethics were approved by the institutional review board. Patients provided written and verbal consent before entering the study. Patients undergoing THA between January 2007 and April 2008 were eligible. Exclusion criterion included previous hip surgery of the involved hip. Of the 86 consecutive patients receiving primary hip arthroplasties during the study period, 79 patients (83 hips) met the inclusion criteria. Patients were randomly allocated to either the anterolateral approach of Röttinger (n = 42) or the Hardinge lateral approach (n = 41). All data were collected prospectively. Observers were blinded.

Preoperative Data

Preoperative data were collected including demographics, preoperative diagnosis, body mass index (BMI), associated pathology or previous surgery of knee(s) or contralateral hip, presence of chronic back pain, and the American Society of Anesthesiologists (ASA) classification. Hip function, general health, and quality of life were assessed with the Harris Hip Score (HHS), Postel and Merle d'Aubigné (PMA) hip score, and Short Form–36v1[5] (SF-36v1; QualityMetric, Lincoln, RI) health questionnaire. Baseline preoperative hemoglobin and hematocrit were recorded. Preoperative standing pelvis and hip radiographs were obtained. Femoral offset was expressed as the ratio of the distance between the lateral cortex of the greater trochanter to the teardrop and the interteardrop distance (Fig. 1). Wiberg center edge angle and femoral neck-diaphysis angle were defined on a true anteroposterior radiograph as described by Lauenstein. *Coxa vara* was defined as a femoral neck-diaphysis angle less than or equal to 120°; and *dysplasia*, as a center edge angle less than or equal to 30° (Table 1).

Surgical Procedures

A single experienced hip surgeon (PC) performed all procedures. Five comprehensive MIS cadaveric training courses were completed before the study start date. All patients received a general anesthetic. Antibiotic prophylaxis (cefazolin) was given before incision as well as 8 and 16 hours postoperatively.

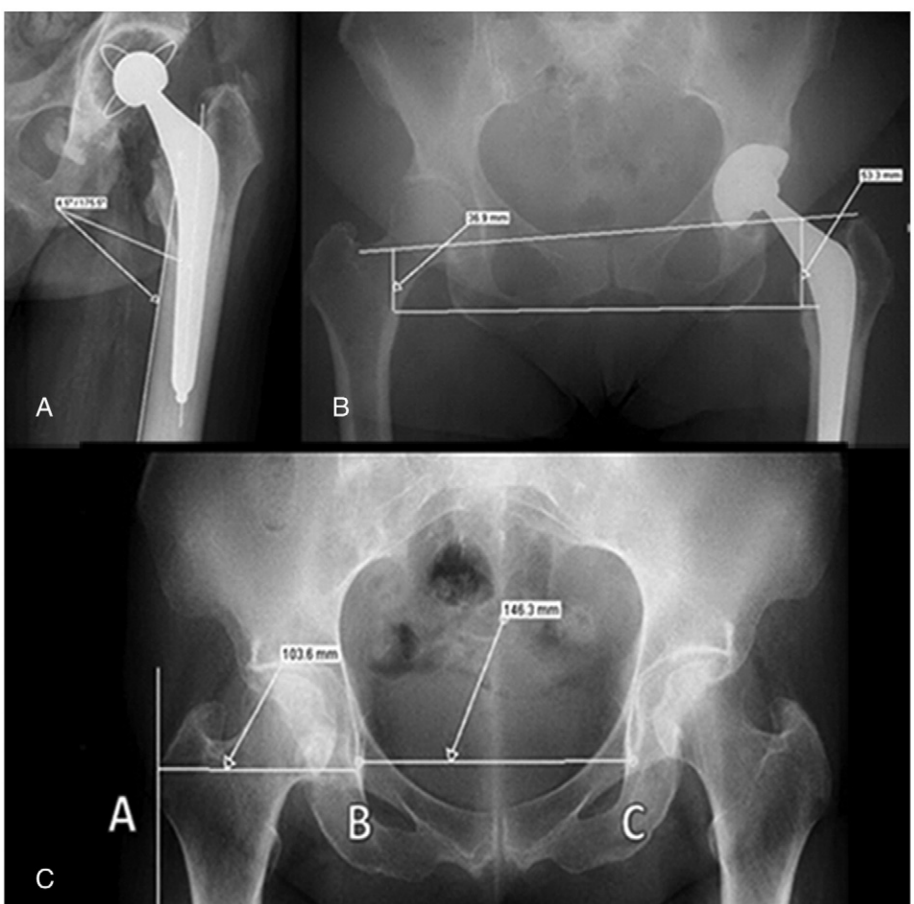

Fig. 1. Radiographic measurements. (A) Screening for valgus or varus malposition greater than 2°. (B) Measurement of femoral length discrepancy. (C) Measurement of femoral offset.

Table 1. Demographics

	ALMIS (n = 42)	LTHA (n = 41)	*P*
Sex (F:M)	30:12	27:14	.584
Side (R:L)	22:20	16:25	.218
Age (y)	66.7 ± 10.1	63.1 ± 10.2	.102
BMI (kg/m^2)	30.6 ± 6.1	29.4 ± 5.5	.330
Preoperative HHS	37.4 ± 15.5	40.2 ± 12.9	.363
Preoperative PMA hip score	8.8 ± 2.3	9.8 ± 1.7	.024
SF-36v1 physical health score			
Physical functioning	19.2 ± 12.9	21.7 ± 12.2	.360
Role physical	26.8 ± 24.3	32.9 ± 14.2	.165
Bodily pain	21.8 ± 13.3	24.4 ± 10.4	.325
General health	39.8 ± 13.7	33.9 ± 10.0	.026
PCS	24.70 ± 5.46	25.33 ± 4.75	.576
SF-36v1 mental health score			
Vitality	38.6 ± 14.2	31.8 ± 10.9	.018
Social functioning	40.8 ± 20.9	42.1 ± 18.3	.764
Role emotional	77.8 ± 30.12	76.4 ± 23.9	.822
Mental health	45.5 ± 11.6	45.1 ± 10.4	.853
MCS	44.95 ± 7.18	43.55 ± 6.45	.353
ASA grade (1/2/3/4)	1/34/7/0	0/35/6/0	.583
Preoperative diagnosis			
Osteoarthritis/AVN	37/5	37/4	.516
Developmental dysplasia	1	3	.308
Coxa vara	1	3	.516
Ipsilateral knee pain or TKA	6	4	.385
Contralateral knee pain or TKA	6	3	.385
Contralateral hip pain or THA	23	15	.061
Low back pain	21	23	.578

The values are given as the mean ± the standard deviation. AVN indicates avascular necrosis; TKA, total knee arthroplasty.

The ALMIS approach was performed as described by Bertin and Röttinger [2]. Patients were positioned in a lateral position, and the distal part of the table was removed (Jupiter; Trumpf Inc, Charleston, SC). An 8- to 10-cm incision was made in line with anterior superior iliac spine and the anterior aspect of the greater trochanter. The intermuscular plane between tensor fascia lata and gluteus medius was exposed, and a U-shaped capsulotomy was made. Femoral neck was osteotomized and removed. The operative leg was kept in external rotation during acetabular reaming. All patients received a cemented femoral stem (Versys; Zimmer Inc, Warsaw, IN) and either cemented or press-fit acetabular component (Allofit; Zimmer Inc). The lateral Hardinge approach was modified according to Thomine et al [6]. The anterior half of the gluteus medius and anterior third of the gluteus minimus tendons were elevated and subsequently repaired. Cemented femoral components were placed in all patients (Tha.lis; Orthogese, Brussels, Belgium), and cemented or press-fit acetabular components (Tha.hy.thi; Orthogese) were placed at the surgeon's discretion. Head diameters between 28 and 32 mm were used for all cases. All bearing surfaces used were metal-on-polyethylene except in those patients younger than 65 years who were considered for ceramic-on-ceramic bearings. Operative time, incision length, surgical complications, and acetabular component size (millimeters) were recorded for each hip.

Immediate Postoperative Period

During postoperative hospitalization, all treating staff were blinded to the technique used. Forty-eight hours postoperatively, hematocrit, hemoglobin, and C-reactive protein (CRP) levels were measured. A standardized postoperative physical therapy protocol was offered to all patients. The program began on the first postoperative day and was supervised by an experienced orthopedic physiotherapist. Weight-bearing status was protected with 2 crutches for a period of 3 weeks and then with one for an additional 3 weeks. Formal physiotherapy was not prescribed after discharge. A standardized analgesic protocol was used for the management of postoperative pain. Paracetamol was administered intravenously for 48 hours and then orally in combination with narcotics delivered on demand on a 2-tier system. The first tier used tramadol (intravenous × 48 hours, then oral), and the second used piritramide (intramuscular × 48 hours) followed by oral hydromorphone. To express postoperative pain, all narcotic administration was recorded and converted to equivalent milligrams of morphine (milligrams per day). All patients received standard venous thromboembolism prophylaxis with subcutaneous low–molecular weight heparin for 4 weeks, but did not receive nonsteroidal anti-inflammatory drug for ectopic calcification prophylaxis. A standard discharge protocol to either home or a rehabilitation facility was based on medical condition, progress in therapy program, and home support. Length of hospitalization, including those transferred to rehabilitation facilities, was recorded. Total hospitalization cost (in euros; €) was calculated based on stay in a standard wardroom. Implant and additional costs (cosmetics, phone, and TV) were deducted.

Postoperative Evaluation

Postoperative follow-up was conducted at 6 weeks, 3 months, 6 months, and 1 year by evaluators blinded to the procedure performed. Patients were clinically and radiographically screened for potential complications including infection, deep vein thrombosis, nerve palsy, dislocation, psoas tendinitis, and signs of aseptic loosening. At 1 year, patients were evaluated using the HHS, PMA, and SF-36v1 [5] scores. Patients were also asked if they felt they were having hip symptoms or whether they had returned to a silent state. Anteroposterior hip radiographs were used to determine if the femoral stem was placed in valgus or varus malalignment. Valgus and varus were considered significant if greater than 2°. Anteroposterior standing pelvic radiographs were used to measure postoperative femoral offset and to determine if any femoral neck discrepancy had

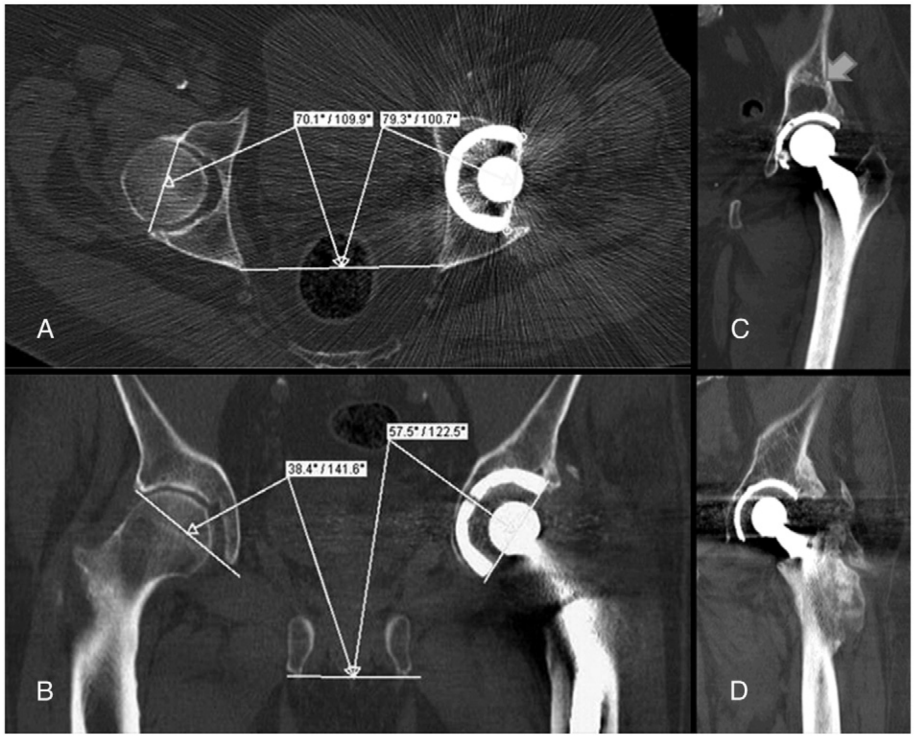

Fig. 2. Computed tomographic scan assessment of cup position, based on the natural position of the contralateral acetabulum, in the transversal and frontal plane. (A) Cup placed in retroversion. (B) Cup placed with an excess of abduction. (C) Residual geode with ALMIS. (D) Heterotopic ossification with ALMIS.

been introduced by the THA. Femoral neck length was measured using the acetabular teardrop as a reference. An iatrogenic discrepancy was considered significant if greater than 5 mm (Fig. 1). A computed tomographic (CT) scan (Siemens Sensation 16; Siemens Inc, Munich, Germany) of the pelvis and proximal femur was used to measure cup inclination and anteversion. Signs of loosening of the stem and cup were classified according to Gruen et al [7] and to DeLee and Charnley [8]. Heterotopic ossification (according Brooker et al [9]) and residual geodes were also assessed (Fig. 2). To ensure reproducible measurements, cup anteversion was measured on cross-sectional images parallel to the superior endplate of S1 [10]. The contralateral hip was used to determine a reference of mean anteversion and inclination for each group (ALMIS, n = 21; lateral transgluteal Hardinge approach [LTHA], n = 26).

Gait Analysis

Gait analysis was performed at 1 year using a plantar pressure plate 10-m walk test (Footscan; RS Scan International, Olen, Belgium). Stride length (centimeters), stance phase duration (percentage of gait cycle), cadence (steps per minute), velocity at slow/fast walking (meters per second), foot progression angle, heel interval (centimeters), and mean foot pressure at stance (newtons per square centimeter N/cm^2) were measured. Hip abduction angle, pelvic obliquity, and trunk inclination angle, as described by Madsen et al [11], were measured at midstance phase using a 2-dimensional camera system. Reflective markers were placed in standardized positions (coracoids and anterior superior iliac spines). Hip abductor strength was measured using a multiaxis force platform (Satel, Blagnac, France). Patients were asked to stand for 15 seconds in a single leg stance to record the lateral translation of the center of gravity (COG) in millimeters. When hip abductors are weak, the upper body is lurched toward the affected hip to compensate abductor insufficiency and COG is shifted in the same direction [12] (Fig. 3). Both operative and nonoperative limbs were recorded. Only those patients with unilateral THA were included (ALMIS n = 19; LTHA n = 23).

Statistical Analysis

Statistical analysis was completed with the assistance of the SPSS software package version 15.0 (SPSS Inc, Chicago, IL). A Kolmogorov-Smirnov test for normal distribution was used. Dichotomous values were analyzed with the χ^2 test for categorical data and with the Student *t* test for numerical values. The Fisher exact test was substituted for χ^2 if one of the values in the contingency table was less than 5. A P value < .05 was considered to be significant.

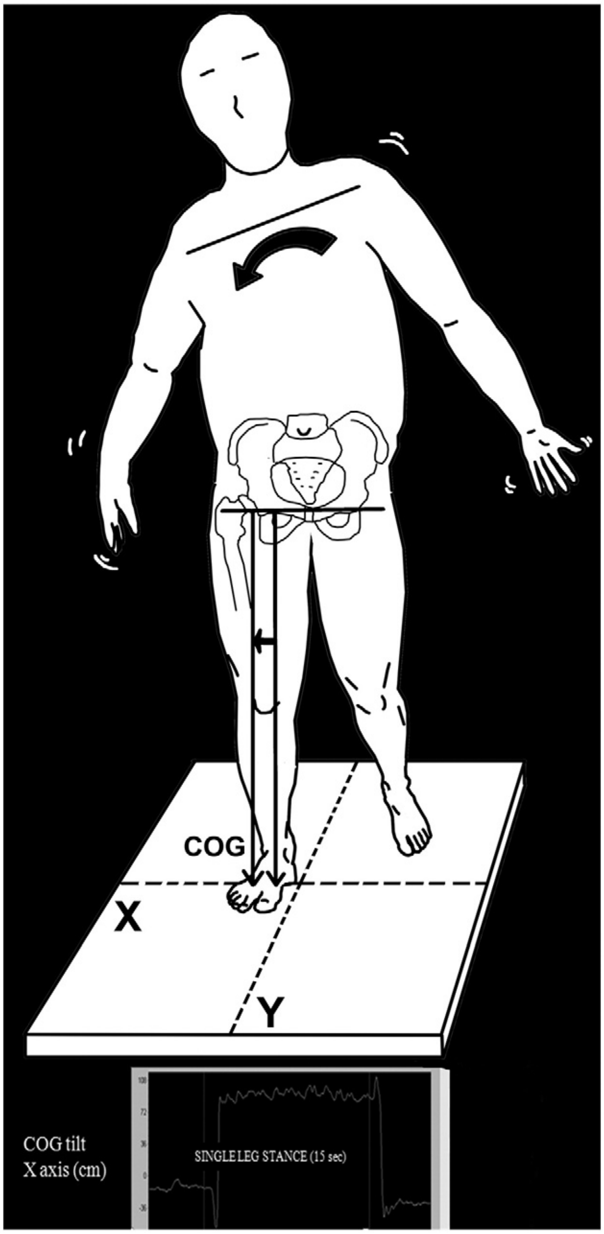

Fig. 3. Multiaxis force platform assessment: the patient was asked to stay in prolonged (15 seconds) single leg stance while the mean lateral translation of their COG was measured. When hip abductors are weak, the upper body is lurched toward the affected hip to compensate abductor insufficiency and COG is shifted in the same direction.

Results

Patient Demographics

Both ALMIS and LTHA groups were homogeneous for all preoperative demographics and characteristics (Table 1), except for a small but significant difference in the PMA score (9.8 ± 1.7 vs 8.8 ± 2.3; *P* = .024). The physical component summary and mental component summary of the SF-36v1 were similar even if the ALMIS group had significantly higher scores in the general health domain (39.8 ± 13.7 vs 33.9 ± 10.0; *P* = .026) and the vitality domain (38.6 ± 14.2 vs 31.8 ± 10.9; *P* = .018). Both groups were overweight (30.6 vs 29.4 kg/m^2) but had a good general health as measured by ASA. The diagnosis was for the most part a primary osteoarthritis, and 50% of patients presented with chronic low back pain.

Surgical Data

Comparing factors at the time of surgery revealed that the ALMIS group had significantly shorter incisions (9.5 ± 1.4 vs 14.8 ± 3.3 cm; $P = 10^{-12}$). However, mean length of surgery was longer in the ALMIS group (114.12 ± 21.47 vs 95.78 ± 18.53 minutes; *P* = .000078). Furthermore, the ALMIS operative time was not significantly different between the first 21 cases and the following 21 (112.0 ± 19.6 vs 116.2 ± 23.5 minutes; *P* = .529). No intraoperative complications such as femoral shaft, calcar and greater trochanter fractures, and cortical perforation were observed in either group. Excessive acetabular reaming occurred with no significant differences between groups (ALMIS = 1, LTHA = 2; *P* = 1.00). Mean acetabular cup size was 52.6 ± 3.4 mm in the ALMIS and 51.4 ± 2.6 mm in the LTHA (*P* = .062).

Early Postoperative Results

Surgical blood loss, estimated by 48-hour postoperative hemoglobin and hematocrit levels, was found to be significantly less in the ALMIS group (Table 2). The drop in hematocrit for ALMIS was 10.1% ± 1.5% compared with 12.5% ± 3.9% with LTHA (*P* = .008); and the drop in hemoglobin was 3.3 ± 1.3 vs 4.2 ± 1.2 g/dL (*P* = .003), respectively. The mean change in CRP was not significantly different (14.2 ± 7.4 vs 13.8 ± 5.7 mg/dL; *P* = .797).

Analgesic consumption in the postoperative period tended to be less in the ALMIS group but without

Table 2. Early Postoperative Data

Domain	ALMIS (n = 42)	LTHA (n = 41)	*P*
Hemoglobin (g/L)			
Preoperation	13.7 ± 1.4	13.8 ± 1.3	.883
48 h postoperation	10.4 ± 1.5	9.6 ± 1.5	.418
Difference	3.3 ± 1.3	4.2 ± 1.2	.003
Hematocrit (%)			
Preoperation	41.1 ± 3.8	41.8 ± 3.8	.098
48 h postoperation	31.1 ± 4.6	29.3 ± 4.9	.008
Difference	10.1 ± 4.2	12.5 ± 3.9	.797
CRP 48 h postoperation (mg/dL)	14.2 ± 7.4	13.8 ± 5.7	.084
Equianalgesic morphine requirement (mg/d)	17.5 ± 12.2	23.3 ± 17.9	.692
Length of hospitalization (d)	8.7 ± 2.3	8.9 ± 2.0	.244
Total hospitalization cost without implants (€)	2879.1 ± 265.6	2959.6 ± 353.9	.512
No. of required transfers to rehabilitation unit	3	2	

The values are given as the mean ± the standard deviation.

significant difference (23.3 ± 17.9 vs 17.5 ± 12.2 mg/d; *P* = .084). Mean length of hospital stay was similar between the 2 groups (8.7 ± 2.3 vs 8.9 ± 2.0 days; *P* = .692). The majority of patients were discharged home directly. Few patients required transfer to rehabilitation facility (3 vs 2, respectively; *P* = .512). Average cost of hospitalization based on a stay in a standard ward room was similar in both groups (€2879 ± €265 vs €2960 ± €354; *P* = .244).

Midterm Postoperative Results

Three patients were lost to follow-up during the first postoperative year: 1 (2.4%) of the 42 patients in the ALMIS group (congestive heart failure) and 2 (4.9%) of the 42 patients in the LTHA group (participation retracted). At 1 year, there were no recorded dislocations or nerve palsies in either group. Two patients developed complications in each group (4.9% vs 5.1%; *P* = 1.00).

In the ALMIS group, 1 patient presented with a deep wound infection (*Staphylococcus epidermidis* and *aureus*) 6 weeks postoperatively. He was first treated by irrigation and debridement with retention of original components and intravenous antibiotics for 6 weeks, without success. He was finally treated with a 2-stage revision. A second patient developed psoas tendinitis, confirmed by ultrasonography and diagnostic bupivacaine injection. After failure of conservative management, an open release of the iliopsoas tendon was performed with good symptomatic relief.

In the LTHA group, we encountered 1 case of psoas tendinitis, which had good symptomatic relief with conservative treatment, and 1 deep vein thrombosis. Both were confirmed by ultrasonography.

Results at 1 Year

At 1 year, 4 patients were lost to follow-up, 2 for ALMIS (1 additional retracted participation) and 2 for LTHA (Table 3). Both groups were performing similarly well in regards to HHS (86.7 ± 14.8 vs 87.4 ± 12.6; *P* = .820) and PMA (16.0 ± 2.2 vs 16.2 ± 1.8; *P* = .778). The SF-36v1 assessment showed similar quality of life improvement in the 8 domains. This was reflected in the physical components summary (PCS; 45.2 ± 10.6 vs 45.0 ± 9.7; *P* = .907) and the mental components summary (MCS; 51.5 ± 9.0 vs 51.6 ± 8.3; *P* = .936) of the score. In the ALMIS group, 60% (24/40) felt that their hip had become silent compared with 44% (18/40) in the LTHA group (*P* = .178). The surgical scar was found to have hypoesthesia more commonly with ALMIS (12.2% [n = 5] vs 0%; *P* = .031). Hypoesthesia was present anterior to the scar in 3 patients and posterior in 2. Dysesthesia was reported in 5 patients, 2 with ALMIS and 3 with LTHA (*P* = .314). Palpation of the scar revealed discomfort more frequently with LTHA (n = 7, 17.9%) than in the ALMS group (n = 2, 4.9%) (*P* = .064).

Table 3. Functional Hip Scores and SF-36v1 General Health Scores at 1 Year

Domain	ALMIS (n = 40; LFU = 2)	LTHA (n = 39; LFU = 2)	*P*
HHS	86.7 ± 14.8	87.4 ± 12.6	.820
PMA hip score	16.0 ± 2.2	16.2 ± 1.8	.778
SF-36v1 physical health score			
Physical functioning	67.5 ± 27.3	72.2 ± 23.5	.417
Role physical	71.9 ± 30.1	78.8 ± 23.3	.254
Bodily pain	65.2 ± 22.3	59.5 ± 24.9	.284
General health	71.3 ± 19.3	65.4 ± 19.1	.174
PCS	45.2 ± 10.6	45.0 ± 9.7	.907
SF-36v1 mental health score			
Vitality	67.5 ± 20.0	67.7 ± 21.0	.967
Social functioning	79.7 ± 24.9	80.8 ± 19.6	.831
Role emotional	87.5 ± 26.9	83.8 ± 24.0	.517
Mental health	67.6 ± 15.9	70.5 ± 15.8	.412
MCS	51.5 ± 9.0	51.6 ± 8.3	.936

The values are given as the mean ± the standard deviation. LFU indicates lost to follow-up.

Passive hip range of motion examination revealed that flexion (96.2 5° ± 10.2° vs 91.3° ± 10.6°; *P* = .038) and adduction (31.2° ±5.6° vs 27.6° ±7.4°; *P* = .020) were slightly better for the standard approach. However, extension was slightly improved with ALMIS (8.5° ± 8.0° vs 4.3° ± 8.1°; *P* = .009). Abduction (32.8° ± 6.5° for ALMIS vs 34.9° ± 7.2° for LTHA; *P* = .189) and external (31.0° ± 8.9° for ALMIS vs 33.5° ± 8.6° for LTHA) and internal rotation (30.5° ± 11.9° for ALMIS vs 30.5° ± 11.5° for LTHA; *P* = .204) were similar in both groups.

Radiographs

Results of radiographic and CT evaluation at 1 year are presented in Table 4. Femoral neck lengthening of greater than 5 mm occurred more commonly with LTHA (38.5%; 15/39) compared with ALMIS (17%; 7/40) (*P* = .047) (Fig. 1). There was no significant difference in iatrogenic femoral neck shortening of greater than 5 mm (*P* = .24) and in varus or valgus malalignment greater than 2° (*P* = .426). Femoral offset was similar in both groups (*P* = .326). The CT scans (Fig. 2), used to look for cup malalignment in the coronal plane, showed no significant difference in malalignment in excessive abduction (*P* = .263) or adduction (*P* = 1) greater than 15° compared with the contralateral hip. Similarly, in the transversal plane, there was no difference in placement in excessive anteversion greater than 15° (*P* = .852) or relative retroversion greater than 15° (*P* = .348) compared with the contralateral hip. There were no signs of femoral component loosening in either group. Two patients with ALMIS and one with LTHA (*P* = 1) showed lucency in Gruen zone II [8] of the acetabulum, which may represent excessive acetabular reaming of the medial wall. All cups had good equatorial contact. Heterotopic ossification rates at 1 year of

Table 4. X-Ray and CT Scan Evaluation at 1 Year

	Domain	ALMIS (n = 40; LFU = 2)	LTHA (n = 39; LFU = 2)
X-ray			
Femoral neck lengthening >5 mm	7 (17.0%)	15 (38.5%)	.047
Femoral neck shortening >5 mm	3 (7.5%)	0 (0.0%)	.240
Femoral stem in varus >2°	3 (7.5%)	4 (10.3%)	.436
Femoral stem in valgus >2°	0 (0.0%)	0 (0.0%)	1
Mean preoperative femoral offset†	0.806 ± 0.107	0.792 ± 0.104	.553
Mean postoperative femoral offset†	0.759 ± 0.098	0.780 ± 0.096	.326
CT scan evaluation			
Relative cup retroversion >15°*	4 (10.0%)	7 (17.9%)	.348
Excessive cup anteversion >15°*	6 (15.0%)	5 (12.8%)	.852
Excessive cup abduction >15°*	2 (5.0%)	5 (12.8%)	.263
Excessive cup adduction >15°*	1 (2.5%)	0 (0.0%)	1
Stem loosening	0	0	1
Signs of cup loosening; Gruen zones 1/2/3	0/2/0	0/1/0	1
Residual geodes	11 (27.5%)	6 (15.4%)	.122
Heterotopic ossification; Brooker class ≥II-III	2 (5.0%)	3 (7.9%)	.488

* Cup position was compared with the mean natural position of the opposite unaffected acetabulum; ALMIS group, n = 23/LTHA group, n = 26.
† The values are given as the mean ± the standard deviation.

either Brooker et al [9] class II or II were similar (2 vs 3; P = .488). Residual geodes (Fig. 2) were identified in 27.5% of ALMIS patients compared with 15.4% in the control group (P = .122).

Gait Analysis

Gait laboratory analysis completed at 1 year is presented in Table 5. The 10-m walk test revealed no significant difference between both groups in step length on the operative (P = .348) and unaffected side (P = .961), stance phase on the operative (P = .7) and unaffected limb (P = .75), cadence (P = .958), and velocity (P = .232). Dynamic pressure measurements showed that the foot progression angle of the operative leg was similar between the groups (P = 1). However, in both groups, when compared with the unaffected limb, the operative limb had an internally rotated foot progression. The degree of rotation was significant with ALMIS (10.5° ± 11.6° vs 14.8° ± 8.6°; P = .038) and with LTHA (10.5° ± 11.5° vs 14.0° ± 8.6°;

Table 5. Gait Analysis at 1 Year

Domain	ALMIS (n = 40; LFU = 2)	LTHA (n = 39; LFU = 2)	P
Plantar pressure plate 10-m walking test			
Step length; affected leg (cm)	46.4 ± 13.8	48.2 ± 12.0	.348
Step length; unaffected side (cm)*	48.1 ± 13.0	47.5 ± 12.2	.961
Stance phase; affected leg (% of gait cycle)	13.4 ± 6.6	12.1 ± 4.4	.700
Stance phase; unaffected leg (% of gait cycle)*	11.8 ± 6.8	11.4 ± 4.5	.750
Velocity (m/s)	2.7 ± 1.1	2.8 ± 0.8	.588
Maximal velocity (m/s)	4.1 ± 1.6	4.5 ± 1.5	.232
Cadence (steps/min)	99.6 ± 18.4	99.4 ± 15.4	.958
Foot progression angle; affected leg (°)	10.5 ± 11.6	10.5 ± 11.5	1
Foot progression angle; unaffected (°)*	14.8 ± 8.6	14.0 ± 8.6	.759
Mean foot pressure at stance; affected leg (N/cm^2)*	450.6 ± 212	511.3 ± 221.6	.361
Mean foot pressure at stance; unaffected leg (N/cm^2)*	456.8 ± 203.5	463.2 ± 214.1	.921
Heel interval (cm)	12.1 ± 6.1	9.0 ± 4.9	.014
Frontal plane angles			
Trunk inclination; affected leg (°)	2.2 ± 2.2	1.6 ± 1.6	.143
Trunk inclination; unaffected leg (°)*	0.6 ± 1.7	0.4 ± 1.9	.835
Pelvic obliquity; affected leg (°)	2.1 ± 1.7	2.0 ± 2.1	.905
Pelvic obliquity; unaffected leg (°)*	2.2 ± 2.2	2.5 ± 2.0	.624
Hip abduction; affected leg (°)	80.2 ± 3.2	80.9 ± 4.2	.396
Hip abduction; unaffected leg (°)*	78.3 ± 3.6	79.4 ± 4.0	.411
Multiaxis force platform			
COG tilt in prolonged single leg stance (15 s)			
Mean × axis position; affected leg (mm)	72.6 ± 24.7	74.1 ± 21.3	.428
Mean × axis position; unaffected leg (mm)*	77.6 ± 17.2	78.8 ± 23.3	.221

The values are given as the mean ± the standard deviation.
* Only patients with completely unaffected opposite leg were included: ALMIS group, n = 19/LTHA group, n = 23.

P = .046). Mean foot pressure at stance phase (newtons per square centimeter) was similar in both groups for the operative leg (P = .361) and unaffected leg (P = .921). The heel interval during walking was greater with ALMIS (12.1 ± 6.1 vs 9.0 ± 4.9 cm; P = .014). The dynamic coronal plane measurements of trunk inclination, pelvic obliquity, and hip abduction angles at midstance on the operative side were similar in both groups. During the prolonged single leg stance test on the multiaxis force platform, the displacement of the COG on the coronal plane (x-axis) was similar in both groups (72.6 ± 24.7 vs 74.1 ± 21.3 mm; P = .428).

Discussion

Minimally invasive surgical techniques have become popularized in all fields of medicine over the past decade. These approaches have been applied to THA in an attempt to improve its already successful outcomes. But the superiority of MIS has yet to be born out in the literature. Only 2 small RCTs with limited evaluation of the ALMIS approach as described by Röttinger have been published [3,4]. To our knowledge, this is the first randomized prospective controlled study that offers a full assessment with a follow-up of 1 year on the ALMIS approach.

Despite the experience of the surgeon and the completion of multiple cadaveric training, we would expect a learning curve until full competency is achieved. The duration of the operative time was increased by 20% ((114.12 vs 95.78 minutes) with ALMIS. One would expect that this time would decrease with increasing number of cases completed. This was not observed in this study. This may simply be the result of the increased number of steps that is required to visualize and perform the THA with the minimally invasive procedure.

From our early experience, we encountered a number of technical challenges when learning the Röttinger approach. The main issue encountered was the proper exposure of the femoral shaft. Excessive tension on the posterior femoral neck by Hohmann retractor may result in damage of the fibers of gluteus medius around its insertion to the greater trochanter. This occurred in 12 of the 42 cases performed. A significant release of the capsule on the medial aspect of the neck was required. The capsulotomy had to be brought back to the insertion of the piriformis tendon. The position that allowed for proper exposure of the femur was external rotation (30°), adduction (30°), and extension (30°). The role of the assistant surgeon in maintaining this position is crucial. The second difficulty encountered was efficient access to the acetabulum. The soft tissue constraints on the instruments could result in malalignment of the implants. The tendency was to place the cup too vertically with excessive anteversion. The use of angulated double-offset instruments limited tissue tension. The third challenge with the Röttinger approach might be to avoid sectioning an intermuscular nerve loop that connects the branches of the superior gluteal nerve to the gluteus medius and the tensor fascia latae muscles. This connecting branch has been described in 50% of cases in a cadaveric study [13]. We could only assume that we had preserved it. The clinical consequences of this injury to this branch are unknown.

Despite the smaller operative field, limited visibility, and reduced space to manipulate surgical instruments, there was no statistically significant increase in perioperative complications, including femoral perforation and fractures of the femoral shaft, greater trochanter, or calcar. These results confirm the observations made by D'Arrigo et al [3]. Furthermore, we have shown that we are able to use the same size of reamers and acetabular cups in the Röttinger as the LTHA approach (52.6 vs 51.4 mm). Based on these results, we feel that the decision to use modified truncated reamers [14] is not warranted and does not justify the potential risk of eccentrically reaming the acetabulum.

There was a linear relationship between the length of the incision and BMI in both groups. Using the Röttinger approach, the relationship for incision length (centimeters) = 7.02 + 0.08 × BMI (P = .029). The Hardinge relationship for incision length was 4.44 + 0.35 × BMI (P = .0008). The slope is more important for the Hardinge approach, meaning that there is a more pronounced relationship between BMI and incision length. The relationship between BMI and incision length has previously been reported using a posterior MIS approach [15].

In the immediate postoperative period, the decrease in hematocrit (10.1% vs 12.5%) and hemoglobin (3.3 vs 4.2 g/dL) was slightly less with ALMIS. This difference, even if statistically significant, may not be clinically relevant. D'Arrigo et al [3] also reported a reduction in perioperative blood loss (300 mL) as compared with the Hardinge approach. Randomized controlled trials looking at the posterior MIS offer contradictory results on this topic. Five [16-20] of the 7 studies [3,16-21] did not show any benefits of MIS with regard to blood loss. In addition, the decrease in tissue injury is one of the potential advantages of MIS. The inflammatory response to tissue injury, as measured by CRP, was found to be similar in both groups in our study 48 hours postoperatively. Shitama et al [20] reported similar findings regarding CRP and interleukin-6 levels 24 hours postoperatively in posterior MIS.

Our estimation of postoperative pain as estimated by morphine analgesic intake indicated that, with ALMIS, fewer narcotics are needed. Although less, the difference was not significantly different. These results are supported by previous studies. Using a visual analog pain scale, Wohlrab et al [4] reported a decrease in postoperative pain levels with the Röttinger approach. In addition, Dorr et al [16] showed a reduction in narcotic consumption with posterior MIS. However, 3 RCTs [17,18,21] showed no difference between posterior MIS and the standard approach.

Length of hospital stay (8.7 days), cost of the visit, and transfer to a rehabilitation center were similar in both groups. D'Arrigo et al [3] also reported no differences regarding the length of stay, with an average of 9 days. This trend is confirmed in the posterior MIS RCTs, with no difference reported in 4 studies [17,18,21,22], whereas only 1 RCT [16] showed a slight trend toward a longer stay (2.2 vs 3.1 days). Furthermore, in a systematic review, de Verteuil et al [23] concluded that MIS hip surgery did not have any benefit with regard to health costs as compared with traditional approaches for THA.

During the 12-month follow-up period, complication rates were similar in both groups. Because the surgical and postoperative complications were not increased, we believe that the Röttinger approach is a safe and valid method. In our surgical population, we had one septic ALMIS THA requiring 2-stage revision (2.5%). Of interest, this revision was completed with ease using the standard Hardinge approach, as we had the advantage of not having primary muscle damage and the presence of very limited scar tissue. The clinical outcome was good despite revision, with no deficit in abductor function (no Trendelenburg sign or limp). Minimally invasive surgery does present a potential advantage with regard to the preservation of "muscle stock" for revisions; however, this advantage would need to be proven in further studies.

At the 1-year mark, all patients were subjected to an exhaustive clinical evaluation composed of scores and evaluations widely accepted in current literature. The combination of hip scores and functional health and well-being evaluations were used for complete subjective assessment. D'Arrigo et al [3] and Wohlrab et al [4] have demonstrated a benefit of the Röttinger MIS approach based on the HHS at 6 weeks [3] and on the Western Ontario and McMaster Universities index at 3 months [4] postoperation. This improvement of early postoperative scores is thought to be secondary to decreased surgical trauma. But it may also be associated with the positive psychological effect or Hawthorne effect [24], given that the patient is aware that he/she has been offered a new surgical procedure. In this study, similar hip function, HHS, PMA, and SF-36 scores were seen at 1 year. There was trend toward an increased number of patients with an asymptomatic hip in the ALMIS group. Similar results have been reported for posterior MIS in 3 RCTs that showed no benefit in HHS [19] or PMA [25] at 1 year and no benefit in HHS [21] at 2 years postoperation. Clinical examination of the hip revealed statistically significant differences in ROM between the groups. However, these may not be clinically relevant because they were all within 5°. Such small differences may be attributed to the method of measurement and/or to the preoperative state, which was not assessed.

The Röttinger approach was more commonly associated with increased risk of hypoesthesia through injury of branches of the lateral femoral cutaneous nerve of the thigh. Jameson et al [26] have shown through an anatomical study that the direction of the Röttinger approach is mostly parallel to the branches of this nerve, and this should limit the risk of nerve injury. We did not find a clinical correlation to this.

With the standard radiographic workup at 1 year, we found that the Hardinge approach had an increased risk of iatrogenic lengthening of the femoral neck. We hypothesize that this lengthening may be created to stabilize the THA while it is tested for dislocation risk intraoperatively. In the Hardinge approach, the abductor muscles are released at this time, which may decrease hip stability with subsequent need to lengthen neck of the stem. Femoral offset was not significantly different between the 2 groups.

Reduced visibility, increased soft tissue constraints on instruments, and loss of classic landmarks have been suggested as potential causes to implant malalignment in minimally invasive surgery. This may affect long-term outcomes. On the femoral side, one of the difficulties is to find appropriate landmarks for the neck cut. We found that it was possible to have a reproducible femoral neck cut through the ALMIS approach using the intertrochanteric tubercle as a mark and preoperative templating. On the acetabular side, there is a potential risk to place the cup in excessive abduction and anteversion in the ALMIS approach; however, this was not substantiated in this study. Computed tomographic scan evaluation at 1 year showed good to excellent position of components. As these results have been obtained in an overweight population, we believe that obesity should not be a contraindication to ALMIS. Wohlrab et al [4] found similar results regarding implant position in ALMIS based on standard radiographs.

Development of heterotopic ossification is thought to be increased with significant surgical tissue trauma, length of surgical procedure, and anterior or anterolateral approaches to the hip. Generally, the maturation process takes 9 to 12 months following surgical insult. To avoid a bias, we did not provide patients with any prophylaxis. At 12 months, we found that the ALMIS had similar rates of heterotopic ossification.

Surprisingly, gait laboratory analysis found that there were essentially no benefits for the ALMIS group. Step length, stance phase duration, and mean foot pressure at midstance were similar between groups on both affected and unaffected sides. Cadence and velocity as well were not significantly different. The only difference was the heel interval (greater in ALMIS) and foot progression angle, which tended to be more internally rotated on the operative leg. As no preoperative gait analysis was performed, it is impossible to determine if heel interval difference was present preoperatively. Increased internal rotation could be secondary to femoral stem anteversion; however, we did not evaluate this on CT scans. It is difficult to determine the clinical impact of these findings. The force platform single leg stance test did not reveal any differences between abductor moments in either group. This is the first study, to our knowledge, which offers a gait analysis at 1 year following ALMIS. With posterior MIS, gait analysis has been performed early in the postoperative period [27], at 6 weeks [22,28], and at 3 months [16], all of which have shown similar results.

Some limitations remain in this study. There is a relatively small sample size, with only 79 patients involved. Another inherent weakness is that patients were not blinded to the procedure that they received. Approximately half of the patients in each group presented with chronic low back pain, which may have affected functional scores and gait patterns. Furthermore, it may be difficult to differentiate hip pain due to persistent hip dysfunction secondary to pain from a radiculopathy. Another possible criticism is that the same implants were not used in each group, which could have influenced offset measurement. Cup fixation, cemented or press-fit, was based on surgeon discretion and could possibly affect blood loss, operative time, and postoperative pain. Preoperative gait assessment was not performed, and postoperative assessment was performed only once. Furthermore, kinematic assessment of pelvic motion was completed in 2 dimensions; and calculations were completed manually. This may be sufficient to diagnose differences that are clinically relevant. However, this method is less precise than a 3-dimensional assessment using appropriate software. Finally, this study did not evaluate the patient's perception of minimally invasive surgery. Dorr et al [28] have shown that a good cosmetic result, a limited detriment to body image, and a rapid recovery are important factors that give the patient the feeling that his or her surgery was successful. This feeling increases patient's self-confidence and encourages early autonomy.

Conclusion

This study compares, for the first time in a randomized and prospective fashion, the functional and radiographic results of the anterolateral MIS approach and the standard Hardinge approach. Our results have shown that the Röttinger MIS approach is a valid method for primary THA. However, at 1 year, we were not able to demonstrate any significant advantages regarding patient satisfaction and gait analysis.

In light of our findings in this study, there was no evidence to support us changing from our current practice of a Hardinge lateral approach to an ALMIS approach.

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