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The Safety and Efficacy of the Anterior Approach Total Hip Arthroplasty as per Body Mass Index

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A B S T R A C T

Background: Obesity is associated with component malpositioning and increased revision risk after total hip arthroplasty (THA). With anterior approaches (AAs) becoming increasingly popular, the goal of this study was to assess whether clinical outcome post-AA-THA is affected by body mass index (BMI).
Methods: This multicenter, multisurgeon, consecutive case series used a prospective database of 1,784 AA-THAs (1,597 patients) through bikini (n = 1,172) or standard (n = 612) incisions. Mean age was 63 years (range, 20-94 years) and there were 57.5% women, who had a mean follow-up of 2.7 years (range, 2.0-4.1 years). Patients were classified into the following BMI groups: normal (BMI < 25.0; n = 572); overweight (BMI: 25.0-29.9; n = 739); obese (BMI: 30.0-34.9; n = 330); and severely obese (BMI ≥ 35.0; n = 143). Outcomes evaluated included hip reconstruction (inclination/anteversion and leg-length, complications, and revision rates) and patient-reported outcomes including Oxford Hip Scores (OHS).
Results: Mean postoperative leg-length difference was 2.0 mm (range: −17.5 to 39.0) with a mean cup inclination of 34.8° (range, 14.0-58.0°) and anteversion of 20.3° (range, 8.0-38.6°). Radiographic measurements were similar between BMI groups (P = .1-.7). Complication and revision rates were 2.5% and 1.7%, respectively. The most common complications were fracture (0.7%), periprosthetic joint infection (PJI) (0.5%), and dislocation (0.5%). There was no difference in dislocation (P = .885) or fracture rates (P = .588) between BMI groups. There was a higher rate of wound complications (1.8%; P = .053) and PJIs (2.1%; P = .029) among obese and severely obese patients. Wound complications were less common among obese patients with the 'bikini' incision (odds ratio 2.7). Preoperative OHS was worse among the severely obese (P < .001), which showed similar improvements (Change in OHS; P = .144).
Conclusion: AA-THA is a credible option for obese patients, with low dislocation or fracture risk and excellent ability to reconstruct the hip, leading to comparable functional improvements among BMI groups. Obese patients have a higher risk of PJIs. Bikini incision for AA-THA can help minimize the risk of wound complications.

Obesity is a growing challenge facing the Western healthcare systems, including arthroplasty surgeons. It is estimated that, by the 2030, 20% of the world's adult population will be obese, and this proportion is predicted to continuously increase [1,2]. Obesity is associated with younger age at the time of primary total hip arthroplasty (THA) [2,3]. Although obese patients can expect clinical improvement following THA with a similar survival rate [4], they are at an elevated risk for complications such as infection and dislocation [5,6]. In most studies on the results of THA among

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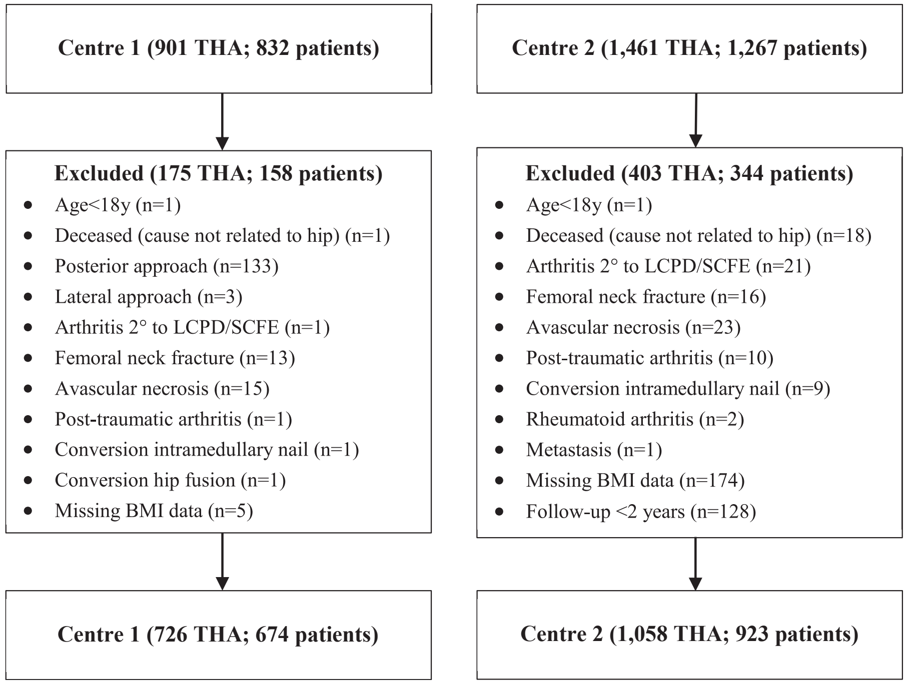

Fig. 1. Flowchart illustrating the inclusion process of the study.

patients who have obesity, an anterolateral [7–9] or posterior approach [7,10] has been used.

The anterior approach (AA) is becoming increasingly popular for a primary THA, with presumed advantages such as enhanced recovery and low dislocation rates [11,12]. However, there is literature reporting an increased complication risk [13,14]. AA is associated with technical difficulties, both on the femoral and on the acetabular side [15], as soft tissues might impede access, increasing risk of component malpositioning, contributing to instability, early loosening, or periprosthetic fractures [16]. In addition, obesity has been described as a risk factor for wound complications in AA due to immune dysfunction and the proximity of the adjacent waist crease, exacerbated in obese patients [17–20].

This study aimed to assess the impact of body mass index (BMI) on the clinical outcome (component position, complication and revision rate, and patient-reported outcome) and to identify factors associated with outcome for patients who have higher BMIs. We hypothesized that the AA can be used safely regardless of BMI, leading to good outcomes, equivalent to those seen in nonobese patients.

Methods

Study Design

This is a retrospective, consecutive case series of prospectively recorded data of patients who underwent primary THA through AA in one of two high volume, tertiary referral institutions (Center 1: The Ottawa Hospital, Ottawa, Canada; and Center 2: Ziekenhuis Oost-Limburg, Genk, Belgium). All six participating surgeons had a minimum of 3 years' experience with and predominantly use AA for primary THA [21]. The study was approved by the ethical committee and all participants signed an informed consent.

Study Population

Between January 1, 2018 and June 1, 2020, 901 THAs were performed in 832 patients in Center 1 by 4 surgeons and 1,461 hip arthroplasties in 1,267 patients in Center 2 by 2 surgeons. The inclusion process has been outlined in a flowchart (Fig. 1). Exclusion criteria were age less than 18 years (n = 2), patients deceased during the follow-up from causes unrelated to THA (n = 19), THA through lateral (n = 3) or posterior approach (n = 133), secondary osteoarthritis to childhood diseases (n = 22), femoral neck fracture (n = 29), osteonecrosis (n = 38), post-traumatic arthritis (n = 11), conversion of an intramedullary nail (n = 10) or hip fusion (n = 1) to THA, rheumatoid arthritis (n = 2), metastasis (n = 1), absent BMI data (n = 179), and follow-up less than 2 years (n = 128). This left 1,784 procedures (1,597 patients) for inclusion (726 THAs in 674 patients from Center 1 and 1,058 THAs in 923 patients from Center 2).

Patients were classified into subgroups based on their BMI at the time of surgery. The groups were BMI < 25.0 (not overweight), BMI 25.0-29.9 (overweight), BMI 30.0-34.9 (obesity), and BMI ≥ 35.0 (severe obesity) [22].

Among all included AA-THAs, 572 had a normal weight (32.1%), 739 were overweight (41.4%), 330 had obesity (18.5%), and 143 severe obesity (8.0%). There were 1,025 men (43.4%) and 1,337 women (56.6%), who had a mean BMI of 27.6 kg/m^2 (range, 15.8-50.8 kg/m^2). The mean age of the cohort was 63 years (range, 20-94 years). Patients who had severe obesity were much younger (61 years, range 28-86 years) in comparison to nonoverweight (64 years, range, 21-94 years; $P = .005$) and overweight (62 years, range 25-91 years; $P = .009$) patients. The mean follow-up was 2.7 years (range, 2.0-4.1 years), with no difference among the obesity groups ($P = .134$) (Table 1).

Surgery and implant characteristics were prospectively collected in the database. All THAs were performed through an AA with the patient in supine position on a standard operating table [23] (n = 1,388) or using a positioning table [24] (n = 396), through a 'bikini' incision (n = 1,172) or a longitudinal incision (n = 612). Three surgeons used the 'bikini' incision; these surgeons also performed a capsular repair, while the others perform a capsulectomy. A fourth surgeon uses the 'bikini' incision for patients who had a BMI ≥ 35 kg/m^2. The Pinnacle acetabular cup (DePuy-Synthes, Warsaw, Indiana, United States) was used in 934 cases (52.4%), the

Table 1
Demographics of the Cohort.

Groups	Mean Age (Y) [Mean (Range)]	Gender (Men:Women) (%)	Mean Follow-Up (Y) [Mean (Range)]	Mean BMI[a] (kg/m^2) [Mean (Range)]	Cemented (Yes:No) (%)
Whole cohort (n = 1,784)	63 (20-94)	43:57	2.7 (2.0-4.1)	27.6 (15.8-50.8)	3:97
No overweight (BMI < 25.0) (n = 572)	64 (21-94)	31:69	2.7 (2.0-3.7)	22.6 (15.8-24.9)	4:96
Overweight (BMI 25.0-29.9) (n = 739)	64 (20-88)	51:49	2.7 (2.0-4.1)	27.3 (25.0-29.9)	4:96
Obesity (BMI 30.0-34.9) (n = 330)	62 (25-9)	44:56	2.6 (2.0-4.1)	31.9 (30.0-34.9)	3:97
Severe obesity (BMI ≥ 35.0) (n = 143)	61 (28-86)	40:60	2.7 (2.0-3.6)	38.8 (35.0-50.8)	7:93
P value[b]	.037[d]	< .001[d]	.134	< .001[d]	.288
Center 1 (n = 726)	65 (20-94)	43:57	2.6 (1.4-4.1)	27.9 (16.5-50.8)	5:95
No overweight (BMI < 25.0) (n = 226)	67 (37-94)	33:67	2.6 (2.0-3.7)	22.3 (16.5-24.9)	4:96
Overweight (BMI 25.0-29.9) (n = 281)	64 (20-86)	53:47	2.6 (2.0-4.1)	27.3 (25.0-29.9)	6:94
Obesity (BMI 30.0-34.9) (n = 137)	62 (31-91)	43:57	2.6 (2.0-4.1)	31.9 (30.0-34.9)	4:96
Severe obesity (BMI ≥ 35.0) (n = 82)	63 (34-86)	40:60	2.6 (2.0-3.6)	39.2 (35.0-50.8)	5:95
Center 2 (n = 1,058)	62 (20-90)	42:58	2.7 (2.0-3.3)	27.3 (15.8-46.1)	3:97
No overweight (BMI < 25.0) (n = 346)	61 (21-89)	30:70	2.8 (2.0-3.3)	22.8 (15.8-24.9)	4:96
Overweight (BMI 25.0-29.9) (n = 458)	63 (20-88)	50:50	2.7 (2.0-3.3)	27.3 (25.0-29.9)	2:98
Obesity (BMI 30.0-34.9) (n = 193)	63 (25-90)	45:55	2.6 (2.0-3.3)	32.0 (30.0-34.9)	3:97
Severe obesity (BMI ≥ 35.0) (n = 61)	61 (28 ± 84)	40:60	2.8 (2.0-3.3)	38.3 (35.0-46.1)	10:90
P value[c]	< .001[d]	.551	< .001[d]	.096	.059

[a] BMI, body mass index.
[b] *P* values comparing different obesity groups.
[c] *P* values comparing both centers.
[d] Statistically significant (*P* value < .05).

G7 acetabular cup (Zimmer-Biomet, Warsaw, Indiana, United States) in 725 cases (40.6%), and the Trilogy cup (Zimmer-Biomet) in 123 cases (6.9%). A total of 1,712 (96.0%) stems were uncemented and 72 stems (4.0%) were cemented in cases of high fracture risk due to osteopenia (Dorr C femur). The decision to use a cemented stem was made during preoperative templating or intraoperatively based on the surgeons' judgment. The most commonly used stems were Corail (DePuy-Synthes) (n = 932), Microplasty (Zimmer-Biomet) (n = 656), Avenir (Zimmer-Biomet) (n = 104), and Taperlock (Zimmer-Biomet) (n = 44). An intraoperative radiograph prior to implantation of final implants was used systematically in most cases in Center 1 (3/4 surgeons); no intraoperative fluoroscopy was used in Center 2 (2 surgeons). Patients allowed weight bearing as tolerated postoperatively without any anterior/posterior hip precautions (n = 1,670) (5 surgeons) or protected weight bearing during the first 2 postoperative weeks (n = 114) (1 surgeon), as per surgeons' preference.

Radiographic Analyses

Standing antero-posterior pelvic radiographs were analyzed and a calibration marker was used to correct for magnification error. The longitudinal rotation of the pelvis was verified as correct when the tip of the coccyx was in line with pubic symphysis [25,26]. If the coccyx deviated ≥ 1 centimeter from the symphyseal line, the X-ray was considered unacceptable for measurement purposes.

A power analysis was performed to determine the minimum number of subjects requiring radiographic reconstruction measurements. A sample size was calculated in SPSS v27 (IBM, Chicago, Illinois) with the intention to detect a difference in cup anteversion of 10°, using an anteversion of 15° ± 10° as a reference [27]. A minimum of 16 patients per group was necessary to achieve sufficient power ($1-\beta = 0.80$, $\alpha = 0.05$).

Two arthroplasty fellowship-trained orthopaedic surgeons performed the following measurements: (1) leg-length discrepancy—defined as the difference of the leg length between the ipsilateral and contralateral hip, measured by the distance between the inter-teardrop line and the inferior margin of the lesser trochanter [28], (2) cup inclination—defined as the angle between the long axis of the cup and a transverse line connecting the bottom edge of the acetabular teardrops [29], and (3) acetabular cup anteversion—defined as the inverse sine of the division between the distance of the short and long axis of the elliptical projection of the rim of the acetabular component [30]. Intraclass correlation coefficient was calculated with a two-way mixed model. A value > 0.75 was considered to have excellent reliability (0-1: no absolute agreement) [31] (Supplementary Table 1).

Outcome Measurements

Clinical, surgical, and hospitalization notes were screened for adverse events. The Clavien-Dindo classification was used to grade complications [32]. Grade 1 complications needed no treatment; these included transient nerve dysesthesia, conservatively treated postoperative hematoma, or greater trochanteric fractures. Grade 2 complications required pharmacologic treatment including superficial wound infections necessitating antibiotics. Grade 3 complications resulted in reoperation and these included dislocations requiring closed reduction or revision, patients who had psoas tendinopathy requiring surgical release, superficial wound infections requiring debridement, periprosthetic joint infections (PJIs) needing revision, periprosthetic fractures requiring open reduction and internal fixation or revision, aseptic loosening or severe metallosis requiring revision, and severe leg-length discrepancies requiring revision. Grade 4 complications were potentially life-threatening complications or resulted in permanent disability and grade 5 complications resulted in death.

Patient-reported outcome measures (PROMs) were obtained at 4 weeks preoperatively and at a minimum of 12 months postoperatively. Those included Oxford Hip Score (OHS) [33]. EuroQOL Five Dimensions Questionnaire [34], PROM Information System (PROMIS) [35] in one Center, and Hip disability and Osteoarthritis Outcome Score (HOOS) [36] and 36-item Short Form Survey (SF-36) [37] in the second center. Length of follow-up was determined from the date of surgery to the last clinical review.

Data Analyses

Statistical analysis was performed using SPSS v27 (IBM). Normal distribution of data was tested with Kolmogorov-Smirnov tests and Q-Q plots. Mann-Whitney U-tests or Kruskal-Wallis tests were used to compare continuous variables between different groups, for

Table 2
Radiographic Measurements per Body Mass Index Group.

Radiographic parameters	No Overweight (BMI < 25.0) (n = 57)	Overweight (BMI 25.0-29.9) (n = 91)	Obesity (BMI 30.0-34.9) (n = 39)	Severe Obesity (BMI ≥ 35.0) (n = 17)	P Value[a]
Leg Length difference (mm) [Mean (range)]	3.6 (−17.5 to 39.0)	1.2 (−11.0 to 11.5)	2.3 (−7.0 to 32.0)	−0.4 (−8.5 to 14.5)	.540
Mean Cup anteversion (°) [Mean (range)]	20.5 (8.0 to 38.6)	20.4 (10.0 to 30.2)	19.4 (8.3 to 27.2)	21.7 (13.0 to 29.5)	.513
Cup inclination (°) [Mean (range)]	33.7 (17.0 to 50.0)	34.8 (14.0 to 58.0)	34.6 (20.0 to 47.0)	38.8 (27.5 to 50.0)	.114

[a] Kruskall-Wallis test.

non-normally distributed data, and independent samples *t*-tests or analysis of variance tests were used for normally distributed data. Paired samples *t*-tests were used to compare preoperative and postoperative values and Chi-squared tests to compare categorical variables. Survival was calculated with failure defined as any reoperation in which any component was changed. Survival data were obtained by Kaplan-Meier analysis [38]. A *P* value of < .05 was considered significant.

Results

Radiographic Measurements

Mean postoperative leg-length difference was 2.0 millimeters (range: −17.5 to 39.0) with a mean cup inclination of 34.8° (range, 14.0-58.0°) and anteversion of 20.3° (range, 8.0-38.6°). There was no difference in any of the radiographic parameters measured (cup anteversion, inclination, and leg-length difference) between different obesity groups (Table 2), with only a slight tendency toward increased cup inclination in patients with higher BMI; however, this difference was not significant (Fig. 2).

Complications and Reoperations

There was no difference in incidence of intraoperative adverse events (calcar fracture or greater trochanteric fracture) (0.7%) among the different groups ($P = .612$).

The overall rate for Clavien-Dindo grade 3 complications within this cohort was 2.5% (45/1,784). Thirty THAs were revised (1.7%); the majority of these were periprosthetic fractures (12/1,784; 0.7%), followed by PJI (9/1,784; 0.5%) and instability (8/1,784; 0.5%) (Table 3). There was no difference in survival rate between the different obesity groups ($P = .095$) (Fig. 3). Patients who had obesity had the highest incidence of wound problems (6/324; 1.8%) in comparison to overweight (4/735; 0.5%; $P = .053$) and not-overweight (1/571; 0.2%; $P = .012$) patients. Similarly, patients who had severe obesity (BMI ≥ 35 kg/m^2) had a significantly higher risk to develop PJI (3/143; 2.1%) in comparison to overweight (3/739; 0.4%; $P = .024$) and not-overweight (3/572; 0.5%; $P = .065$) patients. The incidence of wound complications was lower among patients who had a horizontal 'bikini' incision (odds ratio 2.7; 95% confidence interval 0.9-8.5; $P = .039$).

There were 50 THA (2.8%) patients who had a mean BMI > 40 and a mean age of 63 years (range, 34-84 years). There were 54% women, who had a mean BMI of 42.8 (range, 40.0-50.8). Their mean follow-up was 2.7 years (range, 2.0-3.6 years). Of these, one THA was revised (2.0%) because of a PJI, which was not significantly different in comparison to other obesity groups ($P = .102$). No other intraoperative or postoperative complications were present in this group.

Patient-Reported Outcome Measures

Patients who had a higher BMI had lower preoperative PROM scores (OHS, HOOS, and SF-36) in comparison to patients who had a lower BMI (Table 4 and Fig. 4). Patients who had severe obesity (mean OHS 15.4, range 1.0-36.0) had lower preoperative OHS scores than not-overweight (mean OHS 21.2, range 4.0-44.0; $P < .001$), overweight (mean OHS 19.9, range 1.0-45.0; $P = .002$), and obesity patients (mean OHS 18.7, range 1.0-42.0; $P = .031$). Patients who had severe obesity had a higher change in OHS, HOOS, and SF-36 scores than the other groups, although only significant for change in HOOS quality of life ($P = .006$) (Table 4 and Fig. 4). PROM scores at latest follow-up were lower in groups of patients who had a higher BMI for EuroQOL Five Dimensions Questionnaireand OHS but not anymore for HOOS and SF-36 (Table 4 and Fig. 4). Post hoc analyses revealed that patients who had severe obesity (mean OHS 42.0, range 23.0-48.0) had lower postoperative OHS scores than not-overweight (mean OHS 43.9, range 11.0-48.0; $P < .001$) and overweight (mean OHS 43.9, range, 11.0-48.0; $P = .001$) patients but similar postoperative OHS scores than obese patients (mean OHS 42.1, range 14.0-48.0; $P = .603$).

Discussion

This large, multicenter, multisurgeon, consecutive case series showed that AA-THA is safe and effective in obese patients, even among those who have a BMI ≥ 35 kg/m^2. Reconstruction with AA allowed for reliable component orientation and hip reconstruction even in obese patients, in contrast to other approaches [39,40]. At a follow-up of 2.7 years (range, 2.0-4.1 years), overall complication and revision rates were 2.5 and 1.7%, respectively. The low dislocation (0.5%) and periprosthetic fracture risk (0.7%) was not higher in obese patients. However, patients who had severe obesity had a higher risk to develop PJI (2.1%). Patients who had a higher BMI had lower preoperative PROM scores but sustained a similar improvement in PROMs, further illustrating the efficacy of AA-THA. The risk

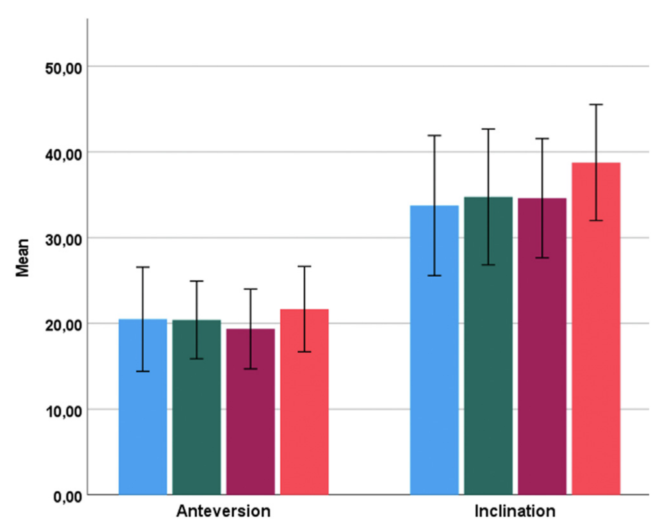

Fig. 2. Radiographic measurements (blue: Body Mass Index [BMI] < 25; green: BMI 25-30; burgundy: BMI 30-35; orange BMI > 35). Figure in color.

Table 3
Complication and Reoperation Rate per Body Mass Index Group.

Complications	Whole Cohort (n = 1,058)	No Overweight (BMI < 25.0) (n = 572)	Overweight (BMI 25.0-29.9) (n = 739)	Obesity (BMI 30.0-34.9) (n = 330)	Severe Obesity (BMI ≥ 35.0) (n = 143)	*P* Value[a]
Preoperative adverse events	12 (0.7)	6 (1.0)	4 (0.5)	2 (0.6)	0 (0.0)	.612
Calcar fracture	10 (0.6)	5 (0.9)	4 (0.5)	1 (0.3)	0 (0.0)	.529
Preoperative greater trochanter fracture	2 (0.1)	1 (0.2)	0 (0.0)	1 (0.3)	0 (0.0)	.519
Grade 1	14 (0.8)	6 (1.0)	3 (0.4)	3 (0.9)	2 (1.4)	.452
Hematoma (conservative)	12 (0.7)	5 (0.9)	2 (0.3)	3 (0.9)	2 (1.4)	.316
Temporary femoral nerve neuropraxia	1 (0.1)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	.548
Postoperative greater trochanter fracture	1 (0.1)	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	.702
Grade 2	6 (0.3)	1 (0.2)	2 (0.3)	3 (0.9)	0 (0.0)	.235
Wound leakage (antibiotics)	6 (0.3)	1 (0.2)	2 (0.3)	3 (0.9)	0 (0.0)	.235
Grade 3 (reoperation)	15 (0.8)	2 (0.4)	6 (0.8)	5 (1.5)	2 (1.4)	.262
Dislocation	3 (0.2)	1 (0.2)	1 (0.1)	1 (0.3)	0 (0.0)	.885
Psoas tendinopathy	6 (0.3)	1 (0.2)	3 (0.4)	1 (0.3)	1 (0.7)	.771
Wound leakage (debridement)	6 (0.3)	0 (0.0)	2 (0.3)	3 (0.9)	1 (0.7)	.121
Grade 3 (revision)	30 (1.7)	8 (1.4)	13 (1.8)	3 (0.9)	6 (4.2)	.073
Recurrent instability	5 (0.3)	2 (0.3)	2 (0.3)	0 (0.0)	1 (0.7)	.588
Periprosthetic fracture	12 (0.7)	3 (0.5)	5 (0.7)	2 (0.6)	2 (1.4)	.720
Periprosthetic joint infection	9 (0.5)	3 (0.5)	3 (0.4)	0 (0.0)	3 (2.1)	.029[b]
Aseptic loosening	2 (0.1)	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	.418
Metallosis	1 (0.1)	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	.702
Leg length discrepancy	1 (0.1)	0 (0.0)	0 (0.0)	1 (0.3)	0 (0.0)	.221

[a] Chi-squared test.
[b] Statistically significant (*P* value < .05).

of infection in obese patients remains a challenge, regardless of approach, even among experienced surgeons, and special attention should be paid to adjunct measure, including postoperative wound management, to minimize this.

The AA has been shown in some studies to lead to superior reconstruction and component orientation accuracy [41,42]. This accuracy does not seem to be adversely affected by BMI. Although BMI did not have an effect on cup position, nor orientation with AA-THA, there was a tendency toward an increased inclination and anteversion in patients who have obesity. It is plausible that during cup positioning, anterior soft tissues push the handle toward increased anteversion and inclination. We would therefore recommend the use of an offset handle during cup placement to help avoid cup malpositioning. Another study assessed the influence of obesity on acetabular cup positioning in AA-THA and also found no difference in cup anteversion/inclination [18], while studies of anterolateral or posterior THA showed that high BMI is a risk factor of cup malpositioning [39,40]. A significantly increased inclination and decreased anteversion among obese patients [43–45] led to the suggestion of using navigation to improve cup orientation when conducting an anterolateral or posterior approach THA in obese patients [46–48]. A large depth of fat can influence the angle of the acetabular component inserter, and pelvic positioning in lateral decubitus is more difficult in obese patients, risking intraoperative pelvic motion [40]. All patients in our study underwent an AA in the supine position, which likely contributes to a more reproducible position of the pelvis during surgery. Leg-length restoration was not affected by obesity in our study, while BMI was found to affect leg-length restoration in posterior approach THA [49].

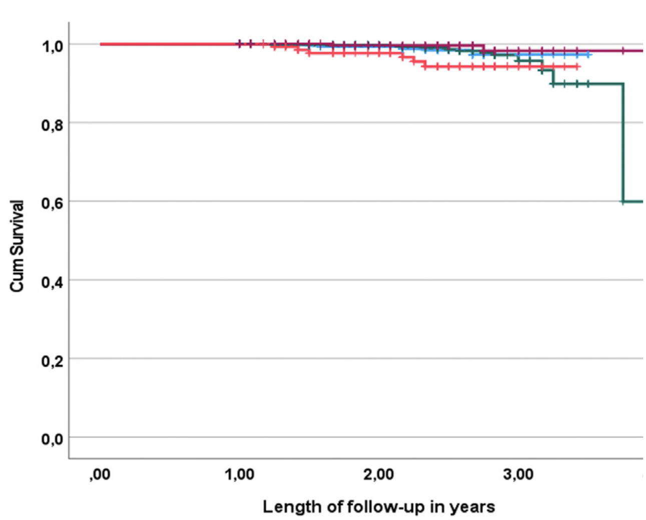

Fig. 3. Kaplan-Meier survival analysis (blue: BMI < 25; green: BMI 25-30; burgundy: BMI 30-35; orange BMI > 35). Figure in color.

Different studies found a higher complication rate after primary THA in patients who have obesity, including instability, periprosthetic fracture, and infection [2,8,9,50,51]. The overall dislocation rate was very low in this cohort (0.5%) and was similar among the different BMI groups. AA appears to be protective against instability, even among obese patients. For other approaches, a dislocation risk up to 3%-7% has been described in severely obese patients [8,9,50]. This is likely the consequence of improved cup positioning and preservation of the muscle envelope with AA. Femoral exposure is one of the technical difficulties associated with AA-THA [15]. Soft tissues in patients with obesity might impede the access to the femoral canal, risking femoral stem malpositioning, and femoral fractures. Although we found a relatively higher periprosthetic fracture rate among patients with severe obesity (1.4%), this was not significantly different than in other groups (0.5%-0.7%). We found no perioperative calcar fractures among patients with obesity; the overall risk was 0.6%. Although no differences in periprosthetic fracture risk were found in this study, it should be acknowledged that femoral exposure can be more difficult in obese patients. All surgeons included in this study are very experienced with AA and femoral exposure in AA is an important aspect of the learning curve [52].

Patients who have severe obesity have a higher risk of PJI (2.1%) in comparison to an overall risk within this cohort (0.5%), and patients who have obesity have a higher risk of wound complications (1.8%) compared to an overall risk (0.6%). Patients who have obesity

Table 4
Preoperative and Postoperative Patient-Reported Outcome scores (PROMs) per Body Mass Index Group.

PROMs	No Overweight (BMI <25.0)	Overweight (BMI 25.0-29.9)	Obesity (BMI 30.0-34.9)	Severe Obesity (BMI ≥35.0)	*P* Value[f]
EQ5D[a]					
Preoperative [Mean (range)]	0.444 (−0.331 to 0.796) (n = 155)	0.403 (−0.358 to 1.000) (n = 183)	0.370 (−0.472 to 1.000) (n = 96)	0.360 (−0.388 to 0.796) (n = 49)	.093
Postoperative [Mean (range)]	0.819 (−0.053 to 1.000) (n = 207)	0.823 (−0.161 to 1.000) (n = 247)	0.802 (−0.053 to 1.000) (n = 128)	0.728 (0.101 to 1.000) (n = 75)	< .001[g]
Change preoperative to postoperative [Mean (range)]	0.372 (−0.357 to 1.081) (n = 145)	0.406 (−0.224 to 1.199) (n = 171)	0.449 (−0.075 to 1.115) (n = 92)	0.349 (−0.061 to 1.123) (n = 48)	.072
OHS[b]					
Preoperative [Mean (range)]	21.2 (4.0 to 44.0) (n = 152)	19.9 (1.0 to 45.0) (n = 174)	18.7 (1.0 to 42.0) (n = 93)	15.4 (1.0 to 36.0) (n = 51)	< .001[g]
Postoperative [Mean (range)]	43.9 (11.0 to 48.0) (n = 206)	43.9 (11.0 to 48.0) (n = 249)	42.1 (14.0 to 48.0) (n = 129)	42.0 (23.0 to 48.0) (n = 75)	< .001[g]
Change preoperative to postoperative [Mean (range)]	22.7 (−6.0 to 40.0) (n = 143)	23.7 (−2.0 to 44.0) (n = 164)	23.4 (3.0 to 41.0) (n = 90)	26.2 (4.0 to 43.0) (n = 50)	.144
HOOS[c] Mean					
Preoperative [Mean (range)]	36.2 (0.8 to 82.6) (n = 193)	34.7 (2.7 to 100.0) (n = 242)	29.8 (1.1 to 85.5) (n = 96)	30.3 (1.5 to 67.1) (n = 29)	.002[g]
Postoperative [Mean (range)]	77.9 (16.7 to 100.0) (n = 172)	79.8 (12.2 to 100.0) (n = 233)	76.8 (12.7 to 100.0) (n = 82)	79.4 (30.8 to 100.0) (n = 26)	.654
Change preoperative to postoperative [Mean (range)]	40.8 (−14.9 to 87.1) (n = 134)	44.1 (−19.6 to 94.2) (n = 171)	45.0 (−17.2 to 81.2) (n = 66)	50.7 (17.6 to 84.9) (n = 20)	.185
HOOS[c] Symptoms					
Preoperative [Mean (range)]	39.5 (0.0 to 85.0) (n = 193)	38.8 (0.0 to 100.0) (n = 242)	35.5 (0.0 to 90.0) (n = 96)	37.9 (0.0 to 90.0) (n = 29)	.323
Postoperative [Mean (range)]	77.9 (10.0 to 100.0) (n = 172)	81.1 (15.0 to 100.0) (n = 233)	78.7 (25.0 to 100.0) (n = 82)	80.6 (40.0 to 100.0) (n = 26)	.624
Change preoperative to postoperative [Mean (range)]	38.7 (−20.0 to 90.0) (n = 134)	42.1 (−20.0 to 100.0) (n = 171)	40.9 (−15.0 to 85.0) (n = 66)	43.3 (−15.0 to 80.0) (n = 20)	.536
HOOS[c] Pain					
Preoperative [Mean (range)]	42.9 (0.0 to 95.0) (n = 193)	41.7 (0.0 to 100.0) (n = 242)	37.4 (0.0 to 92.5) (n = 96)	38.7 (2.5 to 77.5) (n = 29)	.077
Postoperative [Mean (range)]	84.0 (17.5 to 100.0) (n = 172)	84.7 (12.5 to 100.0) (n = 233)	84.8 (10.0 to 100.0) (n = 82)	84.7 (27.5 to 100.0) (n = 26)	.696
Change preoperative to postoperative [Mean (range)]	40.1 (−15.0 to 82.5) (n = 134)	41.8 (−30.0 to 85.0) (n = 171)	45.4 (−10.0 to 80.0) (n = 66)	47.3 (15.0 to 70.0) (n = 20)	.294
HOOS[c] Activities Daily Life					
Preoperative [Mean (range)]	45.8 (0.0 to 94.1) (n = 193)	43.1 (4.4 to 100.0) (n = 242)	36.7 (0.0 to 91.2) (n = 96)	34.0 (0.0 to 69.1) (n = 29)	< .001[g]
Postoperative [Mean (range)]	84.4 (14.7 to 100.0) (n = 172)	86.6 (16.2 to 100.0) (n = 233)	84.2 (16.2 to 100.0) (n = 82)	81.4 (33.8 to 100.0) (n = 26)	.684
Change preoperative to postoperative [Mean (range)]	37.6 (−22.1 to 79.4) (n = 134)	42.1 (−23.5 to 88.2) (n = 171)	45.1 (−4.4 to 100.0) (n = 66)	46.4 (20.6 to 80.9) (n = 20)	.097
HOOS[c] Sport					
Preoperative [Mean (range)]	23.4 (0.0 to 75.0) (n = 193)	21.7 (0.0 to 100.0) (n = 242)	16.5 (0.0 to 100.0) (n = 96)	17.5 (0.0 to 100.0) (n = 29)	.001[g]
Postoperative [Mean (range)]	67.5 (0.0 to 100.0) (n = 172)	68.7 (0.0 to 100.0) (n = 233)	63.6 (0.0 to 100.0) (n = 82)	67.3 (6.3 to 100.0) (n = 26)	.704
Change preoperative to postoperative [Mean (range)]	42.9 (−31.3 to 100.0) (n = 134)	45.8 (−75.0 to 100.0) (n = 171)	45.6 (−68.8 to 100.0) (n = 66)	52.8 (−18.8 to 100.0) (n = 20)	.531
HOOS[c] Quality of Life					
Preoperative [Mean (range)]	29.5 (0.0 to 93.8) (n = 193)	28.2 (0.0 to 100.0) (n = 242)	23.0 (0.0 to 81.3) (n = 96)	23.3 (0.0 to 56.3) (n = 29)	.006[g]
Postoperative [Mean (range)]	76.1 (12.5 to 100.0) (n = 170)	78.1 (12.5 to 100.0) (n = 229)	72.6 (6.3 to 100.0) (n = 81)	84.3 (31.3 to 100.0) (n = 25)	.054
Change preoperative to postoperative [Mean (range)]	44.9 (−31.3 to 100.0) (n = 132)	48.9 (−31.3 to 100.0) (n = 168)	47.8 (−6.3 to 87.5) (n = 65)	66.1 (37.5 to 100.0) (n = 19)	.006[g]
PROMIS[d] Mental					
Preoperative [Mean (range)]	48.0 (28.4 to 67.6) (n = 152)	46.4 (21.2 to 67.6) (n = 188)	47.3 (28.4 to 67.6) (n = 96)	44.3 (25.1 to 67.6) (n = 51)	.049[g]
Postoperative [Mean (range)]	51.0 (25.1 to 67.6) (n = 199)	51.0 (25.1 to 67.6) (n = 235)	48.9 (21.2 to 67.6) (n = 121)	46.0 (21.2 to 62.5) (n = 66)	< .001[g]
Change preoperative to postoperative [Mean (range)]	2.8 (−19.9 to 22.4) (n = 134)	3.3 (−17.2 to 30.6) (n = 164)	3.1 (−14.2 to 25.2) (n = 84)	1.5 (−14.9 to 24.9) (n = 42)	.705
PROMIS[d] Physical					
Preoperative [Mean (range)]	40.4 (19.9 to 61.9) (n = 152)	39.0 (23.5 to 61.9) (n = 188)	38.8 (19.9 to 57.7) (n = 96)	35.8 (23.5 to 50.8) (n = 51)	< .001[g]
Postoperative [Mean (range)]	50.3 (23.5 to 67.7) (n = 199)	49.5 (29.6 to 67.7) (n = 235)	47.1 (23.5 to 67.7) (n = 121)	44.1 (23.5 to 61.9) (n = 66)	< .001[g]
Change preoperative to postoperative [Mean (range)]	9.9 (−15.4 to 29.5) (n = 134)	9.7 (−7.5 to 38.4) (n = 164)	9.6 (−6.9 to 30.9) (n = 84)	7.7 (−5.4 to 24.5) (n = 42)	.404
SF-36[e]					
Preoperative [Mean (range)]	48.8 (11.2 to 83.9) (n = 193)	48.5 (11.1 to 83.3) (n = 242)	43.2 (17.6 to 77.7) (n = 96)	40.8 (10.9 to 69.8) (n = 29)	.001[g]
Postoperative [Mean (range)]	71.0 (17.8 to 88.9) (n = 142)	72.3 (21.2 to 88.4) (n = 168)	67.1 (20.8 to 89.4) (n = 52)	64.4 (31.1 to 90.0) (n = 14)	.457
Change preoperative to postoperative [Mean (range)]	22.1 (−12.3 to 53.9) (n = 108)	25.4 (−21.9 to 57.2) (n = 124)	24.9 (−3.5 to 58.5) (n = 41)	28.0 (6.2 to 56.6) (n = 12)	.295

[a] EQ-5D, EuroQOL Five Dimensions Questionnaire.
[b] OHS, Oxford Hip Score.
[c] HOOS, Hip disability and Osteoarthritis Outcome Score.
[d] PROMIS, Patient-Reported Outcome Measurement Information System.
[e] SF-36, 36-item Short Form Survey.
[f] Kruskall-Wallis test.
[g] Statistically significant (*P* value < .05).

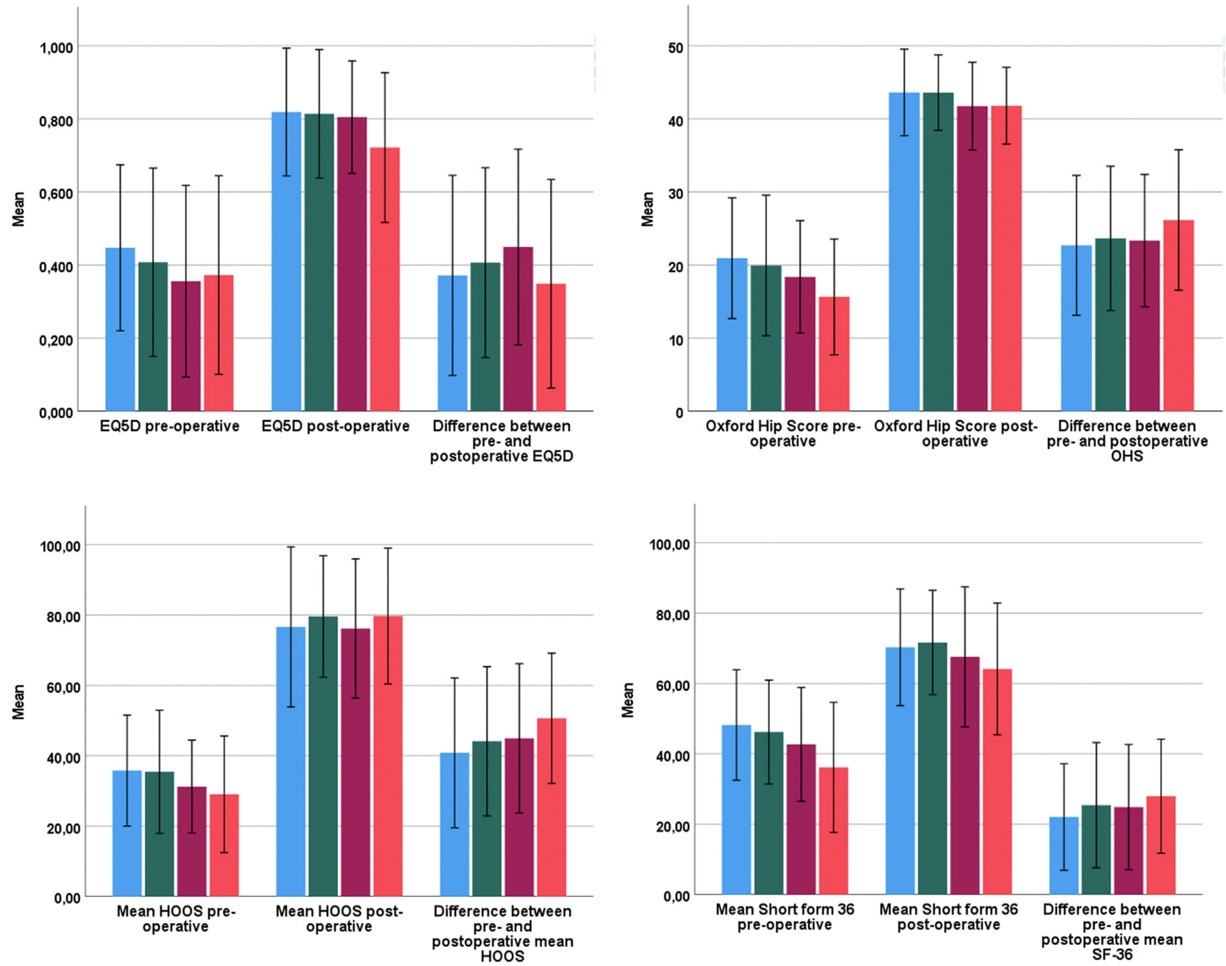

Fig. 4. Preoperative and postoperative PROM scores (blue: BMI < 25; green: BMI 25-30; burgundy: BMI 30-35; orange BMI > 35). Figure in color.

have been shown to be at a higher risk for wound complications and infection due to the increased fat tissue envelope and deeper surgical exploration, adjacency of waist crease with overlying abdominal pannus, and higher prevalence of comorbidities such as diabetes mellitus or immunodeficiency [17–20]. Delayed wound healing compromises the natural skin barrier allowing for bacterial migration in the wound leading to PJI [53]. The wound complication and infection rate was similar or lower in comparison to other studies on the outcome of AA-THA in patients who have obesity. Purcell et al reported a 2.5% incidence of PJI and 2.0% of superficial wound dehiscence among patients who had severe obesity [19]. Antoniadis et al reported a 4.6% incidence of infection requiring reoperation [18]. Jahng et al reported 11.5% wound complications of which 1.9% required a reoperation [54]. Studies on primary THA through an anterolateral approach found a rate of 11% superficial wound problems and 4% deep infection among severely obese patients [50]. Similar to our findings, some studies suggested a horizontal 'bikini' incision to be beneficial for wound healing [53,55]. The bikini incision is oriented along Langer's line, allowing for tension-free healing during the early postoperative period [55]. To minimize the risk of wound complications, possibly contributing to PJI, the bikini incision is recommended. Although incision length was not measured as part of this study, it is plausible that some vertical incisions reached the skin groin crease, which could be associated with an increased risk of slower wound healing [53] due to increased bacterial skin flora [56]. However, the use of the bikini incision is associated with other pitfalls (eg, not extensile) and should thus be used with caution, especially during the learning curve of the AA.

The difference between preoperative and postoperative PROM scores was not different between BMI groups. While patients who had obesity had lower preoperative PROM scores, they can expect similar clinical improvement after THA. Most studies that include PROM scores have found good functional outcomes among obese patients [2,18,57]. Registry data have shown that an increased BMI is associated with significantly smaller improvements in postoperative outcome scores, although these studies did not include AA-THA [58,59]. Due to the increased complication risk, the American Association of Hip and Knee Surgeons workgroup released a statement recommending to delay arthroplasty in patients who have a BMI > 40 kg/m^2 [60]. Recently, the Cleveland arthroplasty group stated that operative eligibility based on BMI alone could potentially restrict access for patients who would benefit from primary THA and can expect improvement in pain, function, and overall quality of life [61], which is supported by our data.

This study has some limitations. It is a retrospective study of prospectively recorded data and there was a lack of complete preoperative and postoperative PROM scores, which were available in only 60% and 70% of patients, respectively. This might have caused bias in interpreting these results. Also, all patients underwent THA through AA and there was no control group to compare risk of complications between different approaches. In addition, all authors have a large experience with AA and therefore these results might not be representative to surgeons in an early stage of the learning curve. The mean follow-up was only 2.7 years (range, 2.0-4.1 years); longer follow-up would be necessary to evaluate the longer-term survival among obese patients treated with AA-THA.

Conclusion

The AA is a safe and effective approach for obese patients undergoing THA. It allows for excellent and reproducible cup orientation and hip reconstruction, even among severely obese patients, without the need for navigation. The risk of dislocation and periprosthetic fractures was low, even among patients who had obesity. Patients who have obesity are at a higher risk to develop wound complications and PJI following AA-THA. A horizontal 'bikini' incision can help to avoid wound complications. Patients who have higher BMI had lower preoperative PROM scores in comparison to patients who had lower BMI, but similar improvement can be expected postoperatively.

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References

[1] Smith K, Smith M. Obesity statistics. Prim Care 2016;43:121–35.
[2] Haynes J, Nam D, Barrack R. Obesity in total hip arthroplasty: does it make a difference? Bone Joint J 2017;99-B:31–6.
[3] Changulani M, Kalairajah Y, Peel T, Field R. The relationship between obesity and the age at which hip and knee replacement is undertaken. J Bone Joint Surg Br 2008;90:360–3.
[4] Yeung E, Jackson M, Sexton S, Walter W, Zicat B, Walter W. The effect of obesity on the outcome of hip and knee arthroplasty. Int Orthop 2011;35:929–34.
[5] Ward D, Metz L, Horst P, Kim H, Kuo A. Complications of morbid obesity in total joint arthroplasty: risk stratification based on BMI. J Arthroplasty 2015;30:42–6.
[6] Friedman R, Hess S, Berkowitz S, Homering M. Complication rates after hip or knee arthroplasty in morbidly obese patients. Clin Orthop Relat Res 2013;471:3358–66.
[7] Andrew J, Palan J, Kurup H, Gibson P, Murray D, Beard D. Obesity in total hip replacement. J Bone Joint Surg Br 2008;90:424–9.
[8] Lübbeke A, Stern R, Garavaglia G, Zurcher L, Hoffmeyer P. Differences in outcomes of obese women and men undergoing primary total hip arthroplasty. Arthritis Rheum 2007;57:327–34.
[9] Davis A, Wood A, Keenan A, Brenkel I, Ballantyne J. Does body mass index affect clinical outcome post-operatively and at five years after primary unilateral total hip replacement performed for osteoarthritis? A multivariate analysis of prospective data. J Bone Joint Surg Br 2011;93:1178–82.
[10] Jackson M, Sexton S, Yeung E, Walter W, Walter W, Zicat B. The effect of obesity on the mid-term survival and clinical outcome of cementless total hip replacement. J Bone Joint Surg Br 2009;91:1296–300.
[11] Wang Z, Hou J-Z, Wu C-H, Zhou Y-J, Gu X-M, Wang H-H, et al. A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. J Orthop Surg Res 2018;13:229. https://doi.org/10.1186/s13018-018-0929-4.
[12] Miller L, Gondusky J, Kamath A, Boettner F, Wright J. Influence of surgical approach on complication risk in primary total hip arthroplasty. Acta Orthop 2018;89:289–94.
[13] Aggarwal V, Elbuluk A, Dundon J, Herrero C, Hernandez C, Vigdorchik J, et al. Surgical approach significantly affects the complication rates associated with total hip arthroplasty. Bone Joint J 2019;101-B:646–51.
[14] Pincus D, Jenkinson R, Paterson M, Leroux T, Ravi B. Association between surgical approach and major surgical complications in patients undergoing total hip arthroplasty. JAMA 2020;323:1070–6.
[15] Spaans A, van den Hout J, Bolder S. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. Acta Orthop 2012;83:342–6.
[16] Hartford J, Knowles S. Risk factors for perioperative femoral fractures: cementless femoral implants and the direct anterior approach using a fracture table. J Arthroplasty 2016;31:2013–8.
[17] Watts C, Houdek M, Wagner E, Sculco P, Chalmers B, Taunton M. High risk of wound complications following direct anterior total hip arthroplasty in obese patients. J Arthroplasty 2015;30:2296–8.
[18] Antoniadis A, Dimitriou D, Flury A, Wiedmer G, Hasler J, Helmy N. Is direct anterior approach a credible option for severely obese patients undergoing total hip arthroplasty? A matched-control, retrospective, clinical study. J Arthroplasty 2018;33:2535–40.
[19] Purcell R, Parks N, Gargiulo J, Hamilton W. Severely obese patients have a higher risk of infection after direct anterior approach total hip arthroplasty. J Arthroplasty 2016;31:162–5.
[20] Russo M, Macdonell J, Paulus M, Keller J, Zawadsky M. Increased complications in obese patients undergoing direct anterior total hip arthroplasty. J Arthroplasty 2015;30:1384–7.
[21] Gofton W, Ibrahim M, Kreviazuk C, Kim P, Feibel R, Beaule PE. Ten-year experience with the anterior approach to total hip arthroplasty at a tertiary care center. J Arthroplasty 2020;35:1281–9.
[22] Canadian Guidelines for Body Weight Classification in Adults. Ottawa: Health Canada: Minister of Public Works and Government Services Canada; 2003.
[23] Corten K, Holzapfel B. Direct anterior approach for total hip arthroplasty using the "bikini incision". Oper Orthop Traumatol 2021;33:318–30. https://doi.org/10.1007/s00064-021-00721-y.
[24] Matta J, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res 2005;441:115–24.
[25] Scheerlinck T. Primary hip arthroplasty templating on standard radiographs. A stepwise approach. Acta Orthop Belg 2010;76:432–42.
[26] Tannast M, Zheng G, Anderegg C, Burckhardt K, Langlotz F, Ganz R, et al. Tilt and rotation correction of acetabular version on pelvic radiographs. Clin Orthop Relat Res 2005;438:182–90.
[27] Lewinnek G, Lewis J, Tarr R, Compere C, Zimmerman J. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978;60:217–20.
[28] Woolson S, Hartford J, Sawyer A. Results of a method of leg-length equalization for patients undergoing primary total hip replacement. J Arthroplasty 1999;14:159–64. https://doi.org/10.1016/s0883-5403(99)90119-5.
[29] Engh C, Griffin W, Marx C. Cementless acetabular components. J Bone Joint Surg Br 1990;72:53–9.
[30] Nho J-H, Lee Y-K, Kim HJ, Ha Y-C, Suh Y-S, Koo K-H. Reliability and validity of measuring version of the acetabular component. Bone Joint Surg Br 2012;94:32–6. https://doi.org/10.1302/0301-620X.94B1.27621.
[31] Fleiss J. The design and analysis of clinical experiments. New York: John Wiley and Sons; 1986.
[32] Wells J, Schoenecker P, Petrie J, Thomason K, Goss C, Clohisy J. Are complications after the bernese periacetabular osteotomy associated with subsequent outcomes scores? Clin Orthop Relat Res 2019;477:1157–63.
[33] Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. J Bone Joint Surg Br 1996;78:185–90.
[34] Group E. EuroQol–a new facility for the measurement of health-related quality of life. Health Policy 1990;16:199–208.
[35] Cella D, Riley W, Stone A, Rothrock N, Reeve B, Yount S, et al. Initial item banks and first wave testing of the Patient-Reported Outcomes Measurement Information System (PROMIS) network: 2005–2008. J Clin Epidemiol 2010;63:1179–94.
[36] Nilsdotter A, Lohmander L, Klässbo M, Roos E. Hip disability and osteoarthritis outcome score (HOOS)–validity and responsiveness in total hip replacement. BMC Musculoskelet Disord 2003;4:10.
[37] Ware Jr J, Sherbourne C. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30:473–83.
[38] Kaplan E, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc 1958;53:457–81.
[39] Callanan M, Jarrett B, Bragdon C, Zurakowski D, Rubash H, Freiberg A, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res 2011;469:319–29.
[40] Meermans G, Grammatopoulos G, Innmann M, Beverland D. Cup placement in primary total hip arthroplasty: how to get it right without navigation or robotics. EFORT Open Rev 2022;7:365–74.
[41] Hamilton W, Parks N, Huynh C. Comparison of cup alignment, jump distance, and complications in consecutive series of anterior approach and posterior approach total hip arthroplasty. J Arthroplasty 2015;30:1959–62.
[42] McGoldrick N, Antoniades S, El Meniawy S, Kreviazuk C, Beaule PE, Grammatopoulos G. Supine versus lateral position for total hip replacement: accuracy of biomechanical reconstruction. Arch Orthop Trauma Surg 2021 [Epub ahead of print].
[43] Brodt S, Jacob B, Windisch C, Seeger J, Matziolis G. Morbidly obese patients undergoing reduced cup anteversion through a direct lateral approach. J Bone Joint Surg Am 2016;98:729–34.
[44] Elson L, Barr C, Chandran S, Hansen V, Malchau H, Kwon Y-M. Are morbidly obese patients undergoing total hip arthroplasty at an increased risk for component malpositioning? J Arthroplasty 2013;28:41–4.
[45] Haffer H, Wang Z, Hu Z, Becker L, Müllner M, Hipfl C, et al. Does obesity affect acetabular cup position, spinopelvic function and sagittal spinal alignment? A prospective investigation with standing and sitting assessment of primary hip arthroplasty patients. J Orthop Surg Res 2021;16:640.

[46] Gupta A, Redmond J, Hammarstedt J, Petrakos A, Vemula S, Domb B. Does robotic-assisted computer navigation affect acetabular cup positioning in total hip arthroplasty in the obese patient? A comparison study. J Arthroplasty 2015;30:2204–7.
[47] Imai N, Takubo R, Suzuki H, Shimada H, Miyasaka D, Tsuchiya K, et al. Accuracy of acetabular cup placement using CT-based navigation in total hip arthroplasty: comparison between obese and non-obese patients. J Orthop Sci 2019;24:482–7.
[48] Sharan M, Tang A, Schoof L, Gaukhman A, Meftah M, Sculco P, et al. Obesity does not influence acetabular component accuracy when using a 3D optical computer navigation system. J Clin Orthop Trauma 2020;14:40–4.
[49] Al-Amiry B, Pantelakis G, Mahmood S, Kadum B, Brismar T, Sayed-Noor A. Does body mass index affect restoration of femoral offset, leg length and cup positioning after total hip arthroplasty? A prospective cohort study. BMC Musculoskelet Disord 2019;20:422.
[50] Chee Y, Teoh K, Sabnis B, Ballantyne J, Brenkel I. Total hip replacement in morbidly obese patients with osteoarthritis: results of a prospectively matched study. J Bone Joint Surg Br 2010;92:1066–71.
[51] Patel A, Albrizio M. Relationship of body mass index to early complications in knee replacement surgery. Arch Orthop Trauma Surg 2008;128:5–9.
[52] Meermans G, Konan S, Das R, Volpin A, Haddad F. The direct anterior approach in total hip arthroplasty: a systematic review of the literature. Bone Joint J 2017;99-B:732–40.
[53] Manrique J, Paskey T, Tarabichi M, Restrepo C, Foltz C, Hozack W. Total hip arthroplasty through the direct anterior approach using a bikini incision can be safely performed in obese patients. J Arthroplasty 2019;34:1723–30.
[54] Jahng K, Bas M, Rodriguez J, Cooper H. Risk factors for wound complications after direct anterior approach hip arthroplasty. J Arthroplasty 2016;31:2583–7.
[55] Swinnen J, Chao A, Tiwari A, Crozier J, Vicaretti M, Fletcher J. Vertical or transverse incisions for access to the femoral artery: a randomized control study. Ann Vasc Surg 2010;24:336–41.
[56] Grice E, Segre J. The skin microbiome. Nat Rev Microbiol 2011;9:244–53.
[57] Haverkamp D, Klinkenbijl M, Somford M, Albers G, van der Vis H. Obesity in total hip arthroplasty–does it really matter? A meta-analysis. Acta Orthop 2011;82:417–22.
[58] Jameson S, Mason J, Baker P, Elson D, Deehan D, Reed M. The impact of body mass index on patient reported outcome measures (PROMs) and complications following primary hip arthroplasty. J Arthroplasty 2014;29:1889–98.
[59] Murgatroyd S, Frampton C, Wright M. The effect of body mass index on outcome in total hip arthroplasty: early analysis from the New Zealand Joint Registry. J Arthroplasty 2014;29:1884–8.
[60] WotAAoHaKSEB Committee. Obesity and total joint arthroplasty: a literature based review. J Arthroplasty 2013;28:714–21.
[61] Arnold N, Anis H, Barsoum W, Bloomfield M, Brooks P, Higuera C, et al., Group, CCOA. Preoperative cut-off values for body mass index deny patients clinically significant improvements in patient-reported outcomes after total hip arthroplasty. Bone Joint J 2020;102-B:683–92.

Appendix

Supplementary Table 1
Interobserver Reliability Agreement.

▪	Intraclass Correlation Coefficient	95% Confidence Interval
Leg length difference	0.927	0.815-0.971
Cup anteversion	0.776	0.435-0.911
Cup inclination	0.973	0.932-0.989