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# Impact of surgical approaches on stem position and hidden blood loss in total hip arthroplasty: minimally invasive vs. posterolateral

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## Abstract

**Background** The surgical approach impacts the outcomes and recovery after total hip arthroplasty (THA), and approaches may affect the stem positioning. Contrary to the general concept of minimally invasive surgery, the direct anterior approach (DAA) results in more intraoperative blood loss. Therefore, the objective of this study was to compare stem positioning and hidden blood loss (HBL) among three surgical approaches: the minimally invasive DAA, Orthopadische Chirurgie Munchen (OCM), and the traditional posterolateral approach (PLA).

**Methods** A total of 201 patients undergoing their first non-cemented THA using the DAA, OCM, and PLA were included in the study. General demographic data, stem alignment, and blood loss were evaluated. Specific comparison measurements included femoral neck anteversion, femoral stem anteversion, alignment of the stem in coronal and sagittal planes, proximal and distal medullary ratios, and femoral offset. Blood loss was measured by calculating Intraoperative Blood Loss (IBL), visible blood loss (VBL), and hidden blood loss (HBL).

**Results** There were no significant differences in age, gender, body mass index, preoperative diagnosis, or femoral Dorr classification among the three groups. The mean surgical time was longer for the DAA and OCM compared to the PLA ( $P < 0.01$ ). IBL was highest in the DAA group and lowest in the PLA ( $P < 0.05$ ). Postoperative stem anteversion were significantly different among the groups, with the DAA showing the greatest anteversion difference ( $P < 0.05$ ). There was no difference in the stem coronal alignment. However, there were more valgus and varus implants in the sagittal plane for the DAA and OCM. The femoral offset reduction was less optimal in the DAA and OCM groups ( $P < 0.05$ ). The proximal and distal medullary ratios were lower in the DAA and OCM ( $P < 0.05$ ). HBL was significantly lower in the DAA and OCM compared to the PLA ( $P < 0.05$ ).

**Conclusion** Minimally invasive approaches such as DAA and OCM offer advantages in muscle and soft tissue preservation, leading to reduced HBL compared to the conventional PLA. However, these approaches present challenges in femoral stem positioning and longer surgical times.

**Keywords** Total hip arthroplasty, Direct Anterior Approach, OCM, Posterolateral Approach, Stem, Hidden blood loss

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## Introduction

Total hip arthroplasty (THA) is commonly performed for severe hip joint diseases and femoral neck fractures. The surgical approach significantly affects outcomes and patient recovery [1, 2]. Recently, minimally invasive approaches such as the direct anterior approach (DAA) and the Orthopadische Chirurgie Munchen (OCM) have become popular [3]. The DAA is performed between muscle and nerve planes, superficially between the sartorius and the tensor fasciae latae, and deeper between the rectus femoris and the gluteus medius [4, 5]. This approach ranks third globally, following the posterolateral approach (PLA) and the direct lateral approach (DLA) [6]. The OCM, refined by Watson Jones and proposed by Berger et al. in 2004, is a minimally invasive anterolateral approach (ALA) that avoids damaging the abductor muscles by operating between the tensor fasciae latae and the gluteus medius [7]. Both DAA and OCM preserve muscle integrity, minimizing muscle and tendon damage and dislocation.

Accurate and stable stem placement in THA is crucial for functional recovery and quality of life [8]. Different surgical techniques can affect the positioning of the prosthetic hip implant [9]. The DAA and OCM present challenges in exposing the femur, which may impact implant positioning accuracy. Studies have reported that the DAA faces greater challenges than the PLA in achieving a neutral sagittal plane during femoral prosthesis insertion [10]. Additionally, Takada R suggested that the OCM approach in the lateral position could affect the accurate placement of the stem during surgery [11]. Incorrect prosthesis positioning can lead to complications such as loosening, impingement, periprosthetic fractures, and dislocation, affecting postoperative joint mobility and limb function. Additionally, previous studies have compared the effects of different approaches on the acetabular prosthesis position after THA [12]; this study, therefore, focuses on the femoral prosthesis position.

Blood loss is a common issue in THA surgeries. Despite effective perioperative blood management, many patients experience varying degrees of anemia postoperatively, with some developing severe anaemia. It is difficult to reconcile this observation with the visible blood loss (VBL) [13]. Hidden blood loss (HBL), first described by Sehat et al. in 2000, refers to blood loss not accounted for by VBL during or after surgery [14]. According to Sehat, HBL accounts for 49% of the total blood loss (TBL) after THA, with some studies reporting rates up to 60% [15]. HBL can constitute a significant portion of TBL and contribute to postoperative anemia [16], increasing the risk of infection, extended hospital stays, and delayed recovery [17]. Factors influencing HBL include gender, age, body mass index (BMI), transfusions, incision length,

hematocrit(Hct) changes, diagnoses, and the use of tranexamic acid [18, 19].

The impact of different surgical approaches on HBL in THA remains unclear. The study examined the effects of DAA, OCM, and PLA on femoral stem positioning and HBL. The objective of this study is to provide clinicians with more accurate and scientific guidance for choosing surgical approaches, thereby optimizing THA outcomes.

## Materials and methods

### Patients

This study included 201 patients who underwent their first cementless THA using the DAA, OCM, and PLA, recruited from Hubei Province Integrated Traditional Chinese and Western Medicine Hospital between September 2018 and April 2023. Patients with ischemic necrosis of the femoral head, osteoarthritis, and post-traumatic arthritis (e.g., acetabular or hip fractures) who provided complete baseline and radiological data were included. Exclusion criteria were previous upper femur bone defect, femur tumor, history of tuberculosis, previous revision surgery, or reconstruction for cancer metastasis. Additionally, patients with concurrent oncological diseases, severe hematological disorders, preoperative coagulation abnormalities, long-term anticoagulant use, poor hip joint development (Crowe III/IV type), severe underlying diseases or mental health disorders, bilateral THA in a single session, or unclear baseline/radiological data were excluded. In the DAA group, patients with BMI < 30 kg/m<sup>2</sup> were included.

### Surgical methods

All surgeries were performed by the same surgical team and the same surgeon under general anesthesia. The double taper rectangular hip prosthesis (Zhengtian Medical Instruments Co, Tianjin, China) was used for all hip.

**PLA** Patients were placed in the lateral decubitus position. A longitudinal incision was made along the posterolateral aspect of the hip. The tensor fasciae latae, piriformis tendon, and short external rotators were released to expose the joint capsule. After assessing the femoral axis direction using a medullary canal probe, the femur was reamed, and a trial femoral stem was inserted. Joint stability and leg length were checked. Following the insertion of the acetabular cup and femoral stem, the joint capsule and short external rotators were repaired as recommended by Pellicci [20].

**DAA** All patients in the DAA group were placed in the lateral decubitus position on an orthopaedic surgical table. During the preparation of the femoral region, the leg was positioned in external rotation, flexion, and abduction. The joint capsule surrounding the greater tro-

chanter was partially released. The proximal femur was elevated utilising an acetabular retractor. The medullary canal was sequentially reamed, and the appropriate femoral prosthesis and trial femoral head were implanted. Following the temporary reduction, the leg length and final implant placement were confirmed.

**OCM** Patients were positioned in the lateral decubitus position on a standard surgical table. An initial 8–10 cm incision was made on the anterolateral aspect of the hip. The space between the tensor fasciae latae and the gluteus medius was bluntly dissected without cutting or detaching muscles. The exposure plane was not extended proximally to minimize the risk of superior gluteal nerve injury [21]. After capsulotomy, the femur was prepared by positioning it in extension, external rotation, and adduction. During THA, trial prostheses were used to ensure maximum stability, and the largest possible femoral stem was inserted into the medullary canal.

#### Perioperative management

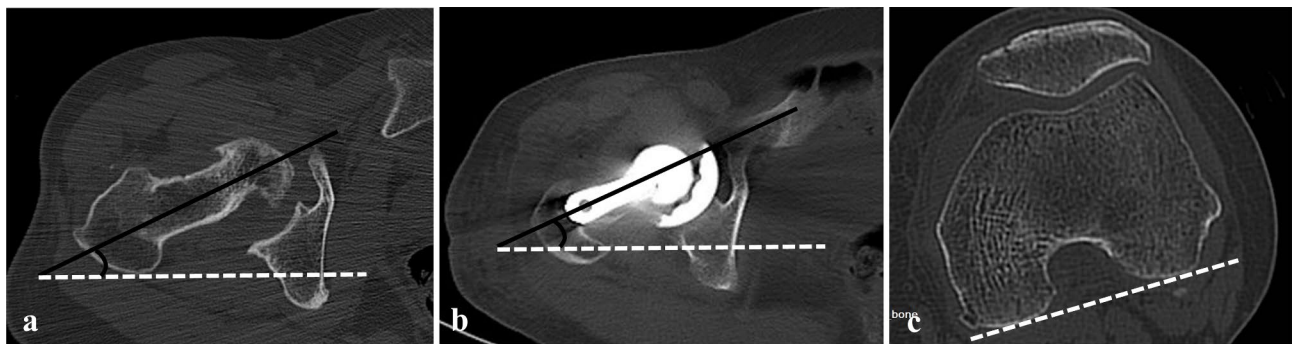
Upon admission, all patients underwent routine preoperative examinations and tests. Anteroposterior pelvic radiographs for hips and lateral radiographs of the proximal femur were routinely obtained on the preoperative and postoperative day 1, representing the functional pelvic plane. Complete laboratory data, including Hct and hemoglobin (Hb) were collected within 3 days before surgery and 3 days postoperatively [22]. Postoperatively, antibiotics were routinely administered to prevent infections. Drainage tubes were not routinely placed unless there was significant bleeding from the surgical wound. Tranexamic acid (1.0 g) diluted in 20 mL of 0.9% sodium chloride solution was locally injected into the hip joint. Anticoagulation therapy with low-molecular-weight heparin was initiated 12 h postoperatively to prevent thrombosis. All patients commenced partial weight-bearing with the assistance of a walker two days post-surgery, followed by full weight-bearing exercises.

#### Evaluation methods

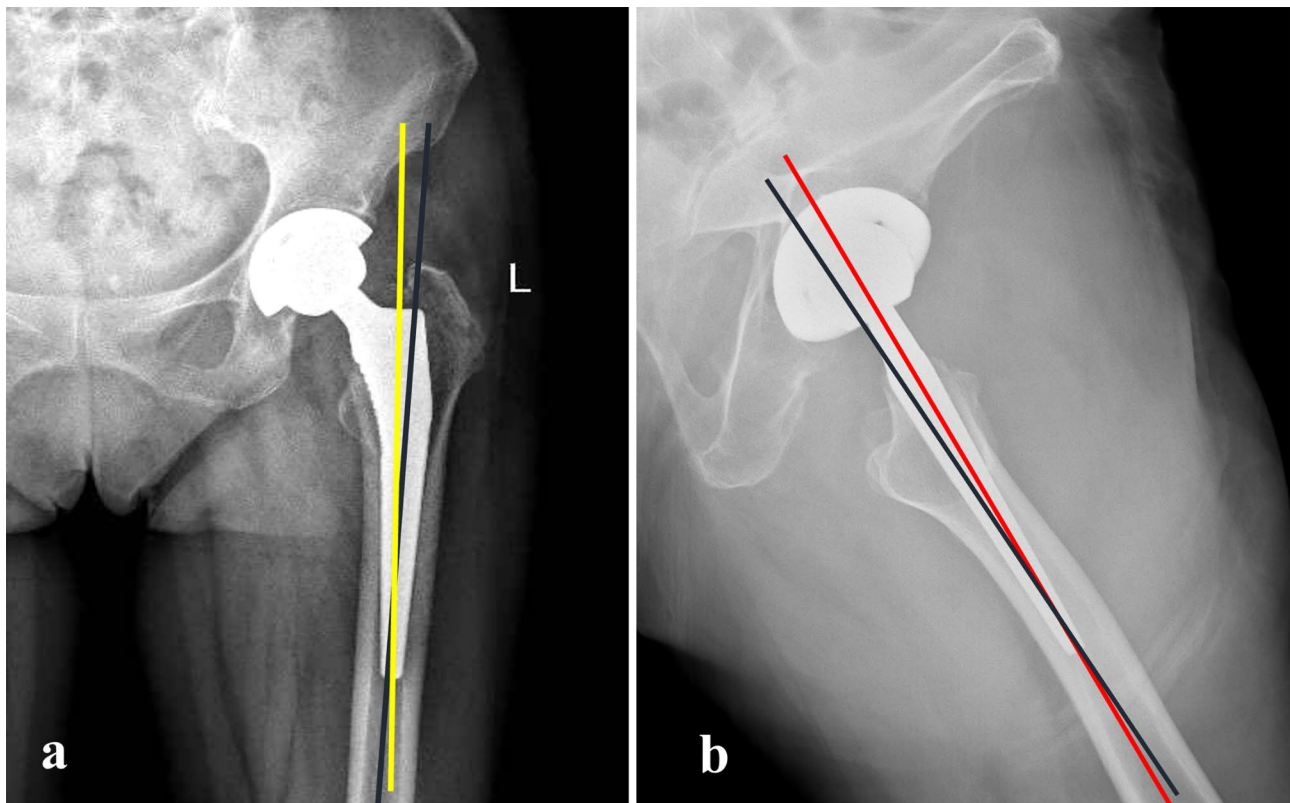
A comparison of background characteristics and surgical data among the three groups was conducted. All patients' general demographic data were collected, including gender, age, BML, duration of surgery, and estimated intraoperative blood loss.

#### Femoral stem prosthesis measurement indicators

Measurements included femoral neck anteversion, femoral stem anteversion, anteversion difference, coronal and sagittal alignment of the stem, and femoral offset (FO). Evaluations were performed by two independent orthopedic surgeons in a blinded manner. All patients underwent preoperative and postoperative CT scans from the pelvis to the knee. Femoral neck anteversion was measured using previously reported methods [11]. The stem anteversion angle is the angle between the long axis of the femoral neck and the line through the posterior condyles of the femur. The difference between the femoral stem anteversion angle and the femoral neck anteversion angle is calculated as the anteversion difference. A positive value indicates that the femoral stem anteversion angle exceeds the femoral neck anteversion angle (Fig. 1). On postoperative anteroposterior and lateral X-rays, we measured the angles between the femoral shaft axis and the femoral stem axis (Fig. 2). Coronal alignment of the femoral stem is defined as neutral, valgus (lateral deviation  $\geq 3^\circ$ ), or varus (medial deviation  $\geq 3^\circ$ ). Sagittal alignment of the femoral stem is defined as neutral, flexed implantation (anterior deviation  $\geq 3^\circ$ ), or extended implantation (posterior deviation  $\geq 3^\circ$ ). The proximal femoral stem filling ratio is calculated by dividing the width of the implant by the width of the femoral canal 10 mm above the lesser trochanter. The distal femoral stem filling ratio is calculated by dividing the width of the implant by the width of the femoral canal 60 mm below the lesser trochanter (Fig. 3) [23]. FO refers to the vertical distance from the femoral long axis to the center of the femoral head (Fig. 4) [24].



**Fig. 1** Measurement of femoral anteversion and postoperative stem anteversion. Femoral anteversion (a) defined as the angle formed by the major axis of the femoral neck and the femoral posterior condylar line (c). Stem anteversion (b) was defined as the angle formed by the major axis of the stem neck and the femoral posterior condylar line (c)



**Fig. 2** Measurement of coronal and sagittal stem alignments. Anteroposterior (a) and lateral (b) views were used to evaluate alignments. Black lines indicate the femoral axis, while the yellow and red lines represent the stem axis in both the anteroposterior and lateral views

### Calculation of hidden blood loss

The primary outcome measure was HBL with secondary outcomes including TBL, VBL, Intraoperative Blood Loss (IBL), estimated blood loss volume (EBV), and the Rate of HBL. Total fluid input and output during surgery and the amount of bleeding during the operation were recorded. VBL included the blood absorbed by gauzes during and after surgery and the volume collected in drainage bags. The patient's blood volume (PBV) and red blood cell loss were calculated using formulas by Nadler [25] and Cross [26]. The HBL is derived by subtracting VBL during and after surgery from the total blood loss.

(1) The PBV was calculated according to the Nadler formula [25].

$PBV (L) = \text{height (m)}^3 \times K1 + \text{weight (Kg)} \times K2 + K3$   
(For male patient:  $K1=0.367$ ,  $K2=0.032$ ,  $K3=0.604$ ; For female patient:  $K1=0.356$ ,  $K2=0.033$ ,  $K3=0.183$ ).

(2) The estimated blood loss volume (EBV) was calculated according to the Gross formula [8]:

$EBV (ml) = PBV (L) \times (\text{Hct pre} - \text{Hct post}) / \text{Hct ave} \times 1000$ .

Hct pre is the initial preoperative Hct, Hct post is Hct on the third day postoperatively, and Hct ave is the average of Hct pre and Hct post.

(3) The hidden blood loss (HBL) was calculated according to the Sehat formula [14]:

$HBL (ml) = EBV (ml) - \text{visible blood loss (VBL)} (IBL + \text{drainage volume})$ .

When transfusion was performed during the perioperative period, the formula was calculated as follows:

$HBL (ml) = EBV (ml) + \text{blood infusion (ml)} - VBL (ml)$ .  
And 1 unit of red blood cells was recorded as 200 ml.

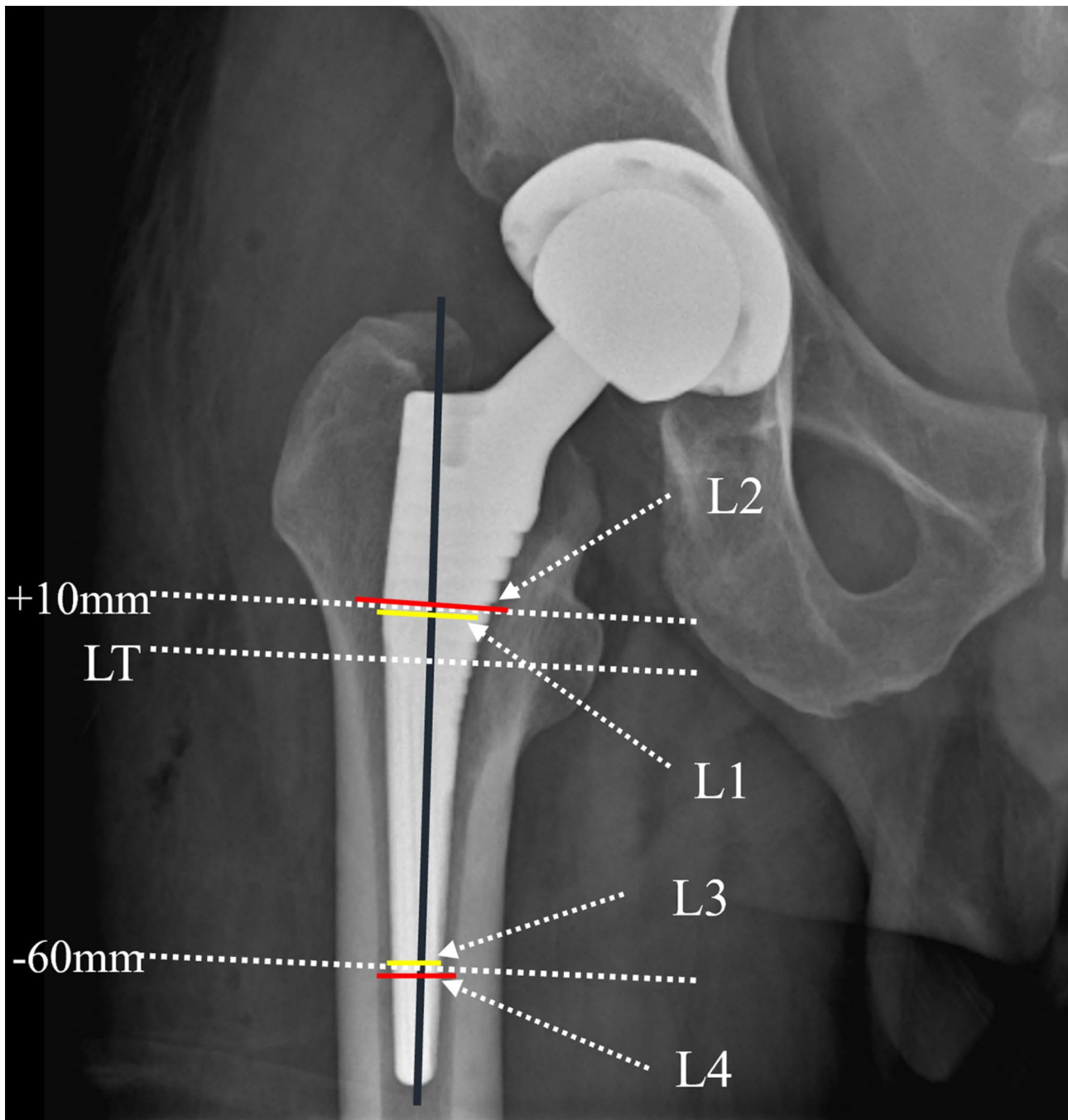
(4) The total blood loss (TBL) was calculated as follows:

$TBL (ml) = VBL (ml) + HBL (ml)$ . And the percentage of HBL (HBL%) was calculated using the following formula:  
 $HBL\% = (HBL/TBL) \times 100\%$ .

(5) HBL % (Hidden blood loss rate) = hidden blood loss / total blood loss  $\times 100\%$ .

### Statistical analysis

We compared femoral prosthesis positioning and HBL among the PLA, DAA, and OCM groups. Data were statistically analyzed using SPSS 2.0 software and were expressed as numbers, percentages (%), and means (standard deviations). Continuous variables were compared using one-way ANOVA or Kruskal-Wallis tests, followed by Scheffe's post-hoc tests. Categorical variables were compared using the chi-square test. A  $P$ -value of  $<0.05$  was considered statistically significant.



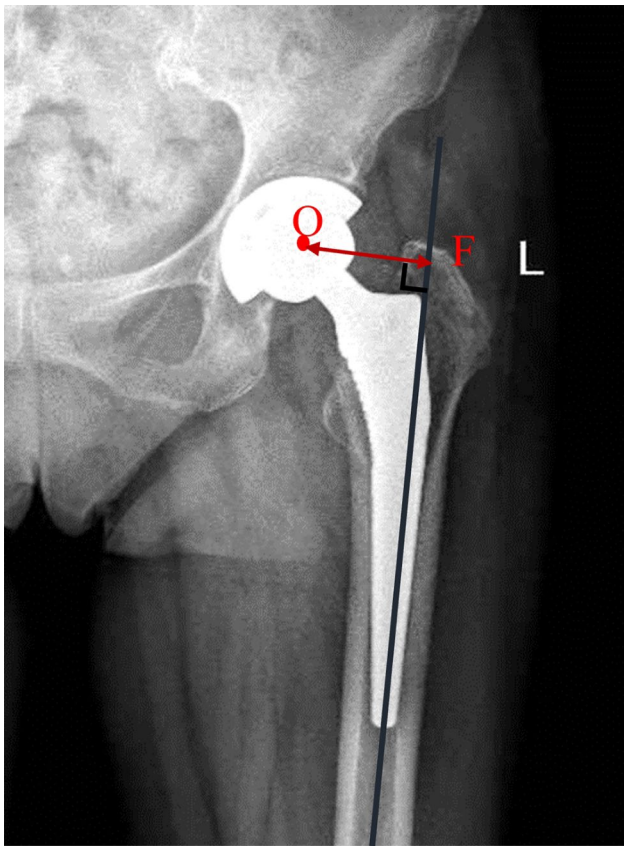
**Fig. 3** Anteroposterior radiographic proximal and distal fit and fill measurements. LT: lesser trochanter. Proximal stem fill (L1/L2) was calculated at a plane 10 mm above the lesser trochanter (LT), and distal stem fill (L3/L4) was calculated at a plane 60 mm below the LT

## Results

### Differences in clinical and surgical data

This study evaluated 106 females and 95 males, with an average age at surgery of 59.7 years (range: 33–86 years). Initial diagnoses included 78 cases of osteoarthritis, 97 cases of osteonecrosis, 6 cases of rheumatoid arthritis, and 20 cases of post-traumatic arthritis. There were 111 cases of Dorr type A, 82 cases of type B, and 8 cases

of type C. The PLA group consisted of 76 patients, the DAA group 66 patients, and the OCM group 59 patients. General demographic data, Dorr classification, clinical diagnosis, duration of surgery, and IBL for the three groups are shown in Table 1. There were no statistically significant differences in age, gender, BMI, preoperative diagnosis, or femoral Dorr classification among the three groups ( $P > 0.05$ ) (Table 1). The average duration



**Fig. 4** Measurement of femoral offset

of surgery was 90.49 min (range: 75–150 min) for the PLA group, 107.5 min (range: 80–170 min) for the DAA group, and 106.62 min (range: 85–170 min) for the OCM group. The DAA and OCM groups had longer surgical times compared to the PLA group ( $P < 0.01$ ; Table 1).

The average IBL was 246.84 mL (range: 100–510 mL) for the PLA group, 283.64 mL (range: 150–480 mL) for the DAA group, and 266.10 mL (range: 120–490 mL) for the OCM group ( $P < 0.05$ ; Table 1). The DAA group exhibited the greatest blood loss, while the PLA group exhibited the least. There were 3 cases of THA dislocation in the PLA group (3.95%), 1 case in the DAA group (1.32%), and 1 cases in the OCM group (1.69%). All dislocations in the PLA group and OCM group were posterior dislocations, while the DAA group had anterior dislocations. There were 2 cases of periprosthetic fractures in each group, with an incidence of 2.63% in the PLA group, 3.03% in the DAA group, and 3.39% in the OCM group ( $P > 0.05$ ).

#### Differences in femoral stem radiological parameters

There were no statistically significant differences in the average femoral neck anteversion angles among the three groups ( $P > 0.05$ ). The postoperative average stem anteversion angles were  $30.07 \pm 2.51^\circ$  for the PLA group,  $31.42 \pm 2.81^\circ$  for the DAA group, and  $30.47 \pm 2.94^\circ$  for the OCM group ( $P < 0.05$ ). The mean postoperative difference in anteversion was  $5.86 \pm 2.32^\circ$  for the PLA group,  $7.23 \pm 3.14^\circ$  for the DAA group, and  $6.42 \pm 3.35^\circ$  for the OCM group ( $P < 0.05$ ), indicating significant differences among the three groups. And there was a significant difference in anteversion differences between the PLA and DAA groups, but no significant differences between the PLA and OCM groups or the DAA and OCM groups. Comparison of stem alignment in the coronal plane showed a higher incidence of varus and valgus implantation in the DAA and OCM groups (PLA: 7.89%, DAA: 10.6%, OCM: 10.17%), but this difference was not statistically significant ( $P = 0.665$ ). In the sagittal plane, more hips in the DAA and OCM groups exhibited a  $3^\circ$  flexion/

**Table 1** Background characteristics and Surgical Data

	PLA (n = 76)	DAA (n = 66)	OCM (n = 59)	P-value
Age (years)	60.95 ± 9.11	59.32 ± 13.62	58.42 ± 10.15	0.900
Gender				0.460
Male	40	28	27	
Female	36	38	32	
BMI (kg/m <sup>2</sup> )	23.67 ± 3.03	23.33 ± 1.94	23.31 ± 2.74	0.338
Diagnosis				0.809
- Osteoarthritis	27	26	25	
- Osteonecrosis	36	34	27	
- Post-traumatic arthritis	10	4	6	
- Rheumatoid arthritis	3	2	1	
Dorr type				0.831
- A	44	37	30	
- B	28	27	27	
- C	4	2	2	
Op time (min), mean	90.49 ± 16.32	107.50 ± 15.68	106.63 ± 16.01	< 0.001
Blood lost (ml), mean	246.84 ± 92.25	283.64 ± 77.00	266.10 ± 78.67	0.012

DAA: direct anterior approach, PLA: posterolateral approach, BMI: body mass index

**Table 2** Radiological parameters of femoral stem

Factors	PLA (n = 76)	DAA (n = 66)	OCM (n = 59)	P-value
Femoral Anteversion (°)	24.21 ± 1.79	24.20 ± 1.80	24.05 ± 1.72	0.95
Stem Anteversion (°)	30.07 ± 2.51	31.42 ± 2.81	30.47 ± 2.94	0.009
Anteversion Difference (°)	5.86 ± 2.32	7.23 ± 3.14	6.42 ± 3.35	0.015
Coronal Alignment				0.199
- Neutral	70 (92.11%)	49 (89.4%)	53 (89.83%)	
- Valgus	2(2.63%)	5(7.58%)	4(6.78%)	
- Varus	4(5.26%)	2(3.03%)	2(3.39%)	
Sagittal Alignment				0.033
- Neutral	70 (92.11%)	48 (72.73%)	45 (76.27%)	
- Flexed	3 (3.95%)	12 (18.18%)	10 (16.95%)	
- Extended	3(3.95%)	6(9.09%)	4(6.78)	
Femoral Offset (mm)	-2.01 ± 2.38	-3.18 ± 2.61	-2.38 ± 2.67	0.026
Proximal Fill (%)	90.79 ± 2.13	88.53 ± 2.94	89.51 ± 2.58	< 0.001
Distal Fill (%)	69.41 ± 3.18	67.61 ± 4.40	68.81 ± 4.76	0.030

**Table 3** Blood loss indexes among the three groups

Indicator	PLA (n = 76)	DAA (n = 66)	OCM (n = 59)	P-value
PBV (L)	4.12 ± 0.13	4.12 ± 0.15	4.11 ± 0.15	0.166
EBV (ml)	897.32 ± 100.77	871.41 ± 97.23	897.15 ± 103.34	0.166
VBL (ml)	364.06 ± 63.94	382.27 ± 39.74	382.26 ± 42.25	0.099
HBL (ml)	559.58 ± 128.55	517.75 ± 137.57	528.45 ± 122.69	0.026
TBL (ml)	923.64 ± 131.72	909.11 ± 158.78	910.71 ± 134.75	0.410
Rate of HBL (%)	60.16 ± 7.18	56.33 ± 6.38	57.52 ± 5.31	< 0.001

PBV: patient's blood volume; EBV: estimated blood loss volume; VBL: Visible Blood Loss; HBL: Hidden Blood Loss; TBL: Total Blood Loss

extension range compared to the PLA group (PLA: 7.89%; DAA: 27.27%; OCM: 23.73%;  $P=0.033$ ). Postoperative FO reduction was  $2.01 \pm 2.38$  mm in the PLA group,  $3.18 \pm 2.61$  mm in the DAA group, and  $2.38 \pm 2.67$  mm in the OCM group ( $P < 0.05$ ). FO recovery was less optimal in the DAA and OCM groups compared to the PLA group. The proximal medullary ratio was  $90.79 \pm 2.13\%$  for the PLA group,  $88.53 \pm 2.94\%$  for the DAA group, and  $89.51 \pm 2.58\%$  for the OCM group ( $P < 0.05$ ). The distal medullary ratio was  $69.41 \pm 3.18\%$  for the PLA group,  $67.61 \pm 4.40\%$  for the DAA group, and  $68.81 \pm 4.76\%$  for the OCM group ( $P < 0.05$ ). Both proximal and distal medullary ratios were lower in the DAA and OCM groups compared to the PLA group, indicating superior medullary filling in the PLA groups (Table 2).

#### Comparison of blood loss indexes

The preoperative average Hb was 13.2 g/dL for the PLA group, 12.8 g/dL for the DAA group, and 13.0 g/dL for the OCM group. Corresponding postoperative average Hb was 11.0 g/dL for the PLA group, 10.7 g/dL for the DAA group, and 11.4 g/dL for the OCM group. There were no statistically significant differences in preoperative average Hb and postoperative average Hb among the three groups ( $P > 0.05$ ). The number of transfusions was 4

in the PLA group, 7 in the DAA group, and 2 in the OCM group. The preoperative average Hct levels were 37.64% for the PLA group, 36.21% for the DAA group, and 36.82% for the OCM group, while the postoperative levels were 30.67%, 31.13%, and 31.52%, respectively ( $P > 0.05$ ). The postoperative drainage volume was 117.22 ml in the PLA group, 98.64 ml in the DAA group, and 116.15 ml in the OCM group; but no significant differences were observed among the three groups. ( $P > 0.05$ ).

There were no statistically significant differences in PBV, VBL, EBV, and TBL among the three groups ( $P > 0.05$ ) (Table 3). The HBL in the PLA group was  $559.58 \pm 128.55$  mL, while the DAA and OCM groups exhibited lower levels of HBL at  $517.75 \pm 137.57$  mL and  $528.45 \pm 122.69$  mL, respectively ( $P < 0.05$ ). Regarding the rate of HBL, the PLA group had a rate of  $60.16 \pm 7.18\%$ , the DAA group  $56.33 \pm 6.38\%$ , and the OCM group  $57.52 \pm 5.31\%$ . Similar to the HBL results, the DAA and OCM groups had lower rates of HBL compared to the PLA group ( $P < 0.05$ ).

#### Discussion

Currently, although the DLA and PLA remain mainstream in THA, the rise of minimally invasive surgery has increased the focus on muscle-sparing techniques. The DAA and OCM are preferred for their reduced trauma, accelerated recovery, and lower incidence of dislocations. However, their visibility limitations may impact femoral stem placement [27]. It is noteworthy that DAA has been associated with a higher incidence of blood loss, as reported in previous studies [28]. This study compares femoral stem positioning and HBL between the minimally invasive DAA, OCM, and the standard PLA.

In this study, all surgeries were performed with the patient in the lateral decubitus position for four reasons: First, traditional posterolateral THA is performed in this position, and the surgical maneuvers for lateral DAA

and OCM are somewhat similar. Second, to minimize variables, we maintained the same patient positioning throughout the study. Third, studies have indicated that supine THA poses a higher risk of sciatic nerve vascular injury compared to lateral positioning [29]. Fourth, research indicates that for cases requiring precise femoral stem insertion, the OCM may be preferable in the lateral position, as it more frequently results in the femoral prosthesis being in the neutral sagittal plane [11].

The accurate positioning of the stem is crucial for the success of THA. Improper positioning can result in complications such as postoperative pain, aseptic loosening, subsidence, fractures, dislocation, and the necessity for revision surgery [30]. Studies have shown that varus-valgus malalignment is closely associated with complications in cementless femoral stems. Accurate placement of the femoral stem can significantly reduce these risks [31]. The DAA has a higher incidence of early peri-prosthetic fractures compared to the PLA and DLA [32]. For instance, 0.8% of DAA surgeries result in Vancouver B type peri-prosthetic fractures within 1–4 weeks post-operation [33]. Moreover, the OCM has been associated with a complication rate of up to 25% related to peri-prosthetic fractures during surgery [34]. In our study, the incidence of periprosthetic fractures showed no significant variation across the groups, which is consistent with the findings of Sershon [35]. Additionally, the incidence of periprosthetic fractures in the OCM group was not as high as previously reported [34], but the frequency of peri-prosthetic fracture in each group fell within the previously reported range of 1–11% for primary hip femoral stems [8]. This discrepancy may be attributed to the surgical learning curve observed in earlier study. Moreover, our study excluded patients with severe underlying diseases and those with a BMI < 30 kg/m<sup>2</sup>. You J believe that obesity makes the OCM procedure more difficult [3].

Previous studies have found significant differences in stem anteversion and sagittal alignment between PLA and ALA, as well as between PLA and DAA [10, 36]. In this study, we focused on the alignment of femoral stem prostheses with DAA, OCM, and PLA, and compared femoral anteversion and FO. We found that the measurement indicators for stem positioning differed among the three approaches. There were no significant differences in coronal alignment among the three groups, but similar to Abe H's previous findings, different approaches resulted in varying sagittal alignments [10]. Our results indicated that the PLA group exhibited the most optimal sagittal alignment, surpassing both the DAA and OCM groups. Abe H reported a higher frequency of flexed implants in DAA compared to posterior approaches, attributing this to the difficulty in elevating the proximal femur during femoral preparation in DAA [10]. Our findings are consistent with this observation.

In terms of stem anteversion angles, there were significant differences between the different approaches [36]. Consistent with previous studies, the postoperative stem anteversion angles were found to be generally greater than the femoral neck anteversion angles across all three approaches [37, 38]. In our study, the DAA group exhibited the greatest anteversion difference, followed by the OCM group, similar to the findings of Takada R, who reported an OCM femoral stem anteversion angle of  $33.9 \pm 12.8^\circ$  [39]. Klasan A reported a higher dislocation rate in the DAA compared to the OCM (2.2% vs. 0.5%) [40]. The changes in anteversion angles may contribute to the higher dislocation rates observed post-DAA. The PLA disrupts the posterior protective structures, and the OCM may also cause some damage to the external rotator muscles [3]. As a result, posterior dislocations were observed in both the PLA and OCM groups. In contrast, the DAA approach, which involves entering through the tensor fasciae latae, sartorius, and rectus femoris while preserving the external rotator muscles, is more prone to anterior dislocations. However, in this study, there was no statistically significant difference in anteversion between the DAA group and the OCM group, nor was there a significant difference in dislocation rates between the two groups. Habe H evaluated preoperative and postoperative anteversion and femoral stem alignment using anatomical femoral stems, finding an average increase of  $5.5^\circ$  in DAA and  $3.0^\circ$  in PLA [10]. Similar to our findings, the DAA group showed greater changes than the PLA group, but the postoperative anteversion differences in our study were larger across all three groups, possibly due to the lateral decubitus position.

As with stem alignment, the match and fill of the femoral stem within the femur are crucial. A good radiological match and fill are associated with an extended survival rate of cementless femoral implants [41]. Biomechanical studies have demonstrated that filling the metaphyseal end of the stem can reduce initial rotational movement and enhance bone fixation [42, 43]. Additionally, optimized stem match and fill improve initial stability and reduce subsidence over the long term [44]. Poor congruence of the stem within the femoral canal is significantly associated with an increased incidence of thigh pain and aseptic loosening [45, 46]. Martel demonstrated that not only is metaphyseal filling crucial, but better diaphyseal matching also leads to more stable implantation. Improved diaphyseal matching has been identified as a crucial factor for better clinical outcomes and lower rates of limping [47]. The results of our study, which employed measurement methods proposed by Joshua Rainey [23], indicated that both proximal and distal medullary ratios in DAA and OCM were lower than in PLA. This finding may explain why anterior approaches remain significant predictors of early femoral failure, with femoral



prosthesis loosening being a major cause of implant fixation failure [32, 48].

In this study, we analyzed the impact of different approaches on FO, which directly influences how body weight is transmitted. Insufficient or excessive FO can alter the lever arm length of the abductor muscles and imbalance soft tissue tension [49]. FO affects outcomes such as hip function and daily activities post-THA [50]. Studies have indicated that increasing FO by up to 5 mm may improve functional outcomes, whereas reducing it may have a detrimental effect [51]. Our results demonstrated that FO recovery was significantly inferior in the DAA and OCM groups compared to the PLA group. This may be due to the challenges in exposing the proximal femur in these approaches. A reduction in FO has been shown to result in a loss of strength in the abductor muscles. Sato et al. demonstrated a correlation between a 5 mm reduction in FO and weaker hip abductors, resulting in shorter strides and slower walking speeds [52]. Rudiger H.A observed that a 20% change in FO resulted in an 8% change in abductor muscle torque and a 16% change in muscle force. This indicates that a reduction in FO necessitates additional abductor muscle effort to maintain normal gait [53]. Studies have shown that the DAA and OCM require greater energy expenditure to maintain static balance post-surgery, as evidenced by elevated average pressure center displacement speeds and path lengths. In contrast, the posterior approach has the least impact on postural parameters during the initial two months post-surgery [54]. This may also be attributed to a reduced FO, which results in a shorter lever arm. Another potential explanation is the disruption of the gluteus medius and quadratus femoris. Burzyński S found that these muscles generate significant resistance torque against external loads [55], and cutting through the upper part of the quadratus femoris during PLA might facilitate increased FO. Intact gluteus medius and quadratus femoris in DAA can make restoring FO during surgery more challenging [56]. In OCM, difficulty exposing the proximal femur involves detaching the anterior part of the greater trochanter's gluteus medius stop point, leading to FO in the OCM group that more closely matches the PLA group.

In this study, both the DAA and OCM exhibited longer surgical times compared to the traditional PLA. However, the difference between the DAA and OCM approaches was minimal. Lazaru P reported similar findings, noting that although the DAA is generally superior to traditional methods, it involves longer surgical times [28]. The reported surgical time for the OCM approach is 114.12 min [57]. Ying-Lin Chen. found an average surgical time of 115.6 min for the DAA in their study, which is close to our findings. They attributed the longer surgical time of the DAA compared to lateral and posterior

approaches mainly to the increased number of intraoperative fluoroscopy checks [12].

In addition to the position of the femoral stem, our study also focused on blood loss for three surgical approaches, particularly HBL. Despite the advent of minimally invasive THA techniques such as DAA and OCM, which aim to spare muscles and reduce surgical trauma, TBL in THA remains substantial, averaging 1.5 L and leading to 20% of patients requiring allogeneic blood transfusion [58]. IBL is typically well estimated, whereas postoperative HBL is often underestimated. Postoperative anemia in patients undergoing THA is frequently attributed to HBL. This occurs primarily due to surgical trauma, which causes extensive blood to enter interstitial spaces and accumulate in cavities such as the joint capsule [59] and hemolysis [18]. Bao concluded that free fatty acids from fat emboli in the bloodstream cause oxidative damage to RBC and Hb membranes, leading to HBL [15]. During THA, the process of marrow rasping and stem placement can damage trabecular bone, intensifying medullary bleeding within the femur. This may continue post-surgery and lead to significant HBL [60]. The adverse effects of HBL include postoperative anemia and complications such as slow wound healing, poor functional recovery, increased risk of infection due to anemia [22], increased risk of lower extremity deep vein thrombosis, higher incidence of cardiovascular events, subcutaneous ecchymosis [61], and prolonged hospital stays [62].

Our study revealed that the amount of blood loss during surgery in the DAA and OCM groups was greater than in the PLA group, consistent with previous studies by Ying-Lin Chen [12] and Cha Y [63]. This may be attributed to the extensive anterior capsular excision, unintentional soft tissue dissection, and longer surgical durations. One of the challenges associated with DAA is the potential for releasing of the proximal femur [64], which can result in prolonged surgical procedures and increased blood loss. The VBL observed in both the DAA and OCM groups was comparable, as reported by Klasan A [40], who also noted a significantly lower transfusion rate in the DAA group.

Our findings are consistent with previous studies [22, 65], which demonstrated significant and considerable HBL following THA across all three groups. This indicates that a substantial proportion of postoperative blood loss remains unobserved. Overall, the HBL in our study falls within the ranges reported by Zha GC [19] and Miao K [18]. The DAA and OCM groups exhibited significantly lower HBL compared to the PLA group, likely due to better muscle and soft tissue preservation with DAA and OCM, reducing postoperative bleeding and tissue damage. Conversely, the PLA inevitably involves cutting the gluteus maximus and disrupting the short external rotators posterior to the hip joint. Although IBL was higher

in the DAA and OCM groups, HBL was less, and TBL showed no significant difference. This may be one reason why patients in the DAA and OCM groups recover more rapidly, have shorter hospital stays, and experience less pain [66].

There were several limitations in this study. Firstly, the study is retrospective. Secondly, the study was conducted by a single surgeon at a single institution, which may have introduced subjectivity. Furthermore, although the study noted that femoral stems were not placed as anticipated, it did not analyze the correlation between femoral prosthesis position and long-term postoperative outcomes or complications. Additionally, the calculation of blood loss was based on a relatively small sample size, which may have introduced bias. Future studies could expand the sample size and utilize multicenter randomized controlled prospective studies to further validate the effects of different surgical approaches on femoral stem position and hidden postoperative blood loss.

## Conclusion

This study highlights the importance of selecting an appropriate surgical approach in THA, as it significantly impacts stem positioning and hidden blood loss (HBL). Compared to the traditional PLA, the minimally invasive DAA and OCM reduce HBL but present challenges in stem positioning and involve longer surgical times. Therefore, choosing the most suitable approach is essential to ensure the success of THA and optimize postoperative outcomes.

## Abbreviations

THA	Total hip arthroplasty
DAA	Direct anterior approach
OCM	Orthopädische Chirurgie München
PLA	Posterolateral approach
DLA	Direct lateral approach
ALA	Anterolateral approach
HBL	Hidden blood loss
TBL	Total blood loss
VBL	Visible blood loss
IBL	Intraoperative blood loss
EBV	Estimated blood loss volume
PBV	Patient's blood volume
BMI	Body mass index
Hct	Hematocrit
Hb	Hemoglobin

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## Author contributions

All the authors have made significant contributions: Gongwu Yuan and Yaoguang Xiao conceived the conception for this manuscript. Zijian Chen performed statistical analysis. Gongwu Yuan and Zhigang Li wrote the primary manuscript. Gongwu Yuan and Ximing Liu edited the manuscript.

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## Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

This is an observational study. The Hubei Provincial Hospital of Integrated Chinese & Western Medicine Ethics Committee has confirmed that no ethical approval is required.

### Informed consent

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

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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