



# Comparison of postoperative outcomes between endoscopy assisted minimal invasive direct anterior approach and bikini direct anterior approach in total hip arthroplasty

Zhibo Deng<sup>1,2</sup> · Hanhao Dai<sup>1,2</sup> · Chao Song<sup>1,2</sup> · Fenqi Luo<sup>1,2</sup> · Yijing Wu<sup>1,2</sup> · Rongsheng Zhang<sup>1,2</sup> · Jun Luo<sup>1,2</sup> · Jie Xu<sup>1,2</sup>

Received: 26 February 2024 / Accepted: 22 June 2024

© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2024

## Abstract

**Background** We have innovatively developed a modified bikini direct anterior approach total hip arthroplasty (THA), endoscopy assisted minimal invasive direct anterior approach (Endo-DAA). The study compared aesthetic appearance of the scar, postoperative radiographic and functional outcomes, and complications of Endo-DAA with Bikini-DAA.

**Methods** Patients who underwent primary THA using Endo-DAA or Bikini-DAA were included. The main innovation of Endo-DAA is the use of minimally invasive 5–7 cm proximal transverse incision and distal puncture with an endoscopy assisted split-type tool to complete the acetabular preparation and prosthesis implantation. Outcomes evaluated included evaluation of scar satisfaction, hip reconstruction including inclination, anteversion and leg-length discrepancy (LLD) and patient-reported outcomes including Harris Hip Scores (HHS) and Forgotten Joint Score (FJS). Follow-up time points included preoperative, 6 weeks, 6 months and 12 months.

**Results** Finally, 195 hips in Endo-DAA and 207 hips in Bikini DAA completed the follow-up. The Endo-DAA group was superior to the Bikini-DAA group in the cosmetic aspects of scars. the cup anteversion angle of Endo-DAA group was significantly better than that in the Bikini-DAA group. The early HHS and FJS of the Endo-DAA group were superior to those of the Bikini-group. Operation time, blood loss, incision length, length of stay and duration to start no-assistive-device walking were also significantly better in the Endo-DAA group. Furthermore, the Bikini-DAA group had a higher incidence of complication.

**Conclusion** Compared with Bikini-incision, Endo-DAA improves patients' subjective satisfaction with scar aesthetics, accelerates rapid recovery of postoperative function, and reduces postoperative complications.

**Keywords** Endoscope · Direct anterior approach · Bikini · Total hip arthroplasty · Complications

---

Zhibo Deng, Hanhao Dai and Chao Song have contributed equally to this work.

✉ Jun Luo  
resoluto@foxmail.com

✉ Jie Xu  
jiexud@126.com

<sup>1</sup> Shengli Clinical Medical College of Fujian Medical University, Fuzhou, People's Republic of China

<sup>2</sup> Department of Orthopedics, Fujian Provincial Hospital, Fujian Medical University, Fuzhou, People's Republic of China

## Introduction

Total hip arthroplasty (THA) is one of the most frequently performed and effective procedures worldwide, with more than 1 million THAs currently performed worldwide each year [1, 2]. With the innovation of technology, THA has many approaches, such as posterior, posterolateral, lateral, the anterolateral approach and direct anterior approach [3]. However, in terms of duration of operation, implant location, learning curve, blood loss, functional outcomes, and complications, there is still no one approach that is completely superior to the others [4–6]. To ensure rapid and comprehensive functional recovery, increasingly THA minimally invasive techniques are being invented by surgeons [7]. Among them, A minimal oblique incision using the

groin cleavage line (bikini incision) DAA achieved encouraging results, especially in improving aesthetics and postoperative scarring [8].

The longitudinal incision length of the traditional DAA is approximately 12 cm [9], and the incision is lateral to the tensor fascia lata. The inconsistency of this incision with the muscle space often makes the operation of the femur side difficult. Bikini-DAA, which is placed in the same direction as groin crease, can reduce the complications of poor incision healing [10]. Leunig et al. [11], also demonstrated that Bikini-DAA has an advantage in controlling wound complications. Bikini-DAA also retains the advantage of using the neuromuscular space to access the joint capsule to significantly reduce soft tissue damage [12]. However, Jin et al. [12] reported that 12% of patients in the Bikini-DAA group developed LFCN complications. In addition to this, the steep learning curve about Bikini-DAA is also causing concern for beginners [13, 14]. Furthermore, Banasiak et al. [5] have shown that Bikini-DAA has a high incidence of lymphedema after surgery.

Bikini incisions in the groin are usually at the same level as the acetabulum, thus it is less extensile compared with the classic longitudinal incision [11]. Surgeons also have difficulty using conventional tools to prepare the acetabular side and implant the prosthesis, and patients who are obese or muscular or who have a short femoral neck or a protruding acetabulum may represent a more specific problem [15]. Therefore, we designed an endoscopy assisted minimal invasive direct anterior approach technique for THA (Endo-DAA-THA). A proximal transverse bikini incision of 5–7 cm and a distal puncture point through the intermuscular space were used to prepare the acetabular side and implant the prosthesis with an endoscopically assisted split-type tool. The initial study in our research center found that Endo-DAA achieved favorable short-term clinical efficacy [16, 17].

This retrospective study was designed to evaluate two different types of DAA: (1) the effect of Endo-DAA on wound aesthetics compared with Bikini-DAA; (2) Radiological differences in implant position when using Endo-DAA compared to Bikini-DAA; (3) Differences in functional outcomes and complications between Bikini-DAA and Endo-DAA.

## Materials and methods

### Patients

The retrospective study, as a single-center study, was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology: the STROBE

Statement [18]. Patients in our hospital who underwent THA using Endo-DAA or Bikini-DAA between 1 January 2019 and 31 December 2022 were enrolled. Inclusion criteria: (i) 18 years old; (ii) Patients receiving a primary unilateral THA for diagnosis of avascular necrosis of the femoral head, neck fracture, congenital hip dysplasia (Crowe type 1, 2), osteoarthritis, rheumatoid arthritis, or post-traumatic arthritis. Exclusion criteria: (i) Patients undergoing revision hip arthroplasty; (ii) Patients who are unwilling to attend regular follow-up visits; (iii) Body mass index (BMI) > 30 kg/m<sup>2</sup>.

The study was approved by the Institutional Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Patient data was collected for research with the informed consent of all patients.

### Surgical technique

#### Anesthesia and position

Both DAA THA (Implant: Pinnacle Acetabular Cup System and Corail/Tri-lock Hip System by DePuy, Johnson and Johnson, USA) procedures were performed randomly by two surgeons (including JX and FL). Prior to this study, both surgeons had performed at least 50 surgeries using either Bikini-DAA or Endo-DAA. The patients were placed in the supine position. The pubic symphysis of patients was aligned with the fold of the operating table. Local infiltration analgesia was performed before skin incision (Fig. 1).

#### Surgical procedure

**Endo-DAA** The intermuscular approach of Endo-DAA was similar to the Bikini-DAA described by Nizam et al. [19]. As described previously [17], 5–7 cm skin incision was placed in the lateral groin crease (Fig. 2A). After entering the gap between tensor fascia latae (TFL) and sartorius, the tissue on the medial side of the Hueter space was placed medial to minimize damage to the lateral femoral cutaneous nerve (LFCN). To expose laterally the vastus lateralis, a branch of the lateral circumflex artery was ligated in the Hueter space. After the anterior articular capsule was dissected like flap shaped. According to the preoperative measurements, the femoral neck was cut off by segmental method to facilitate the removal of the femoral head through the minimally invasive incision (Fig. 2B). A puncture was made on the skin surface located in the muscle space and was 10 cm distal to the main surgical incision. A trocar with 10 mm in diameter was placed in the puncture (Fig. 2C). Next, the preparation of acetabular side was performed under endoscopy (Stryker laparoscope, USA) (Fig. 2D-E). Meantime, the puncture can also be used as an entry point for the modular

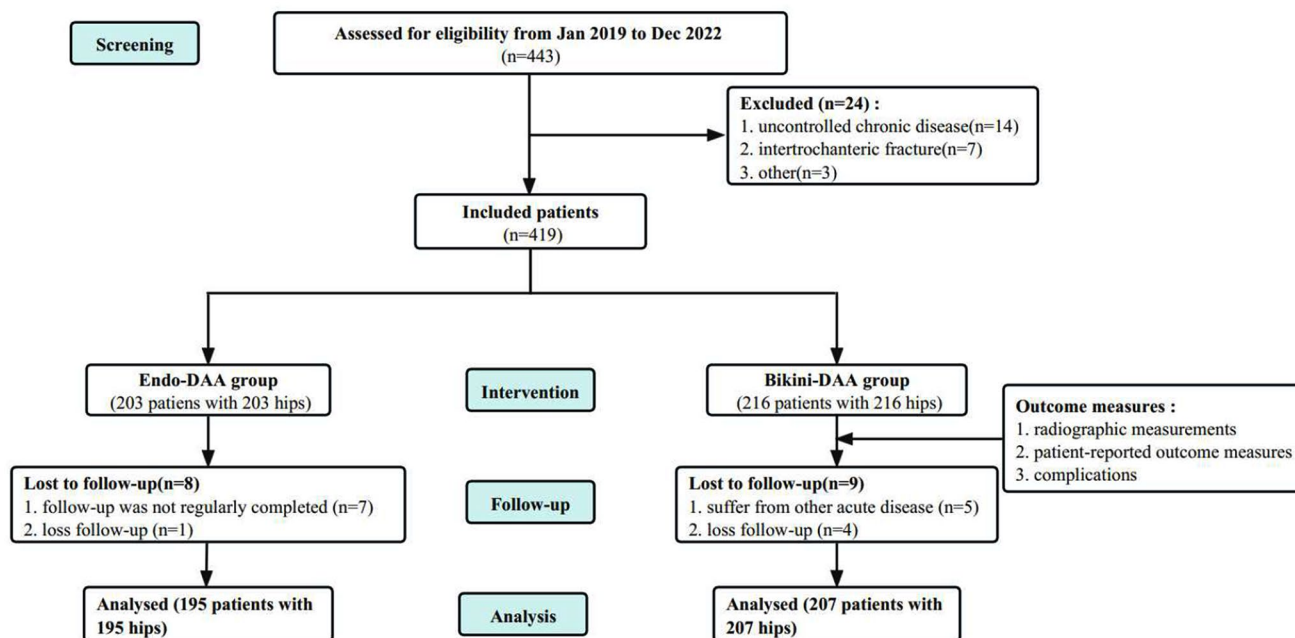
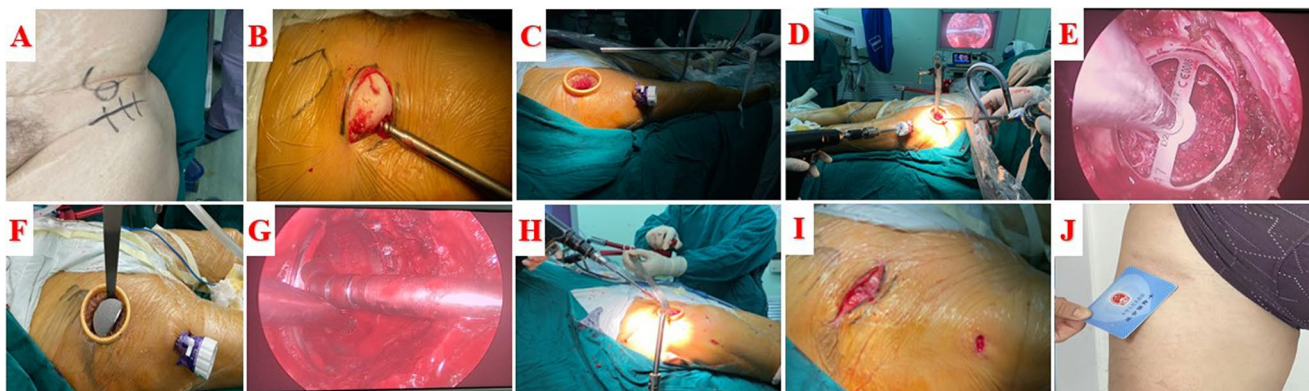


Fig. 1 STROBE flowchart illustrating the inclusion process



**Fig. 2** Procedure of the Endo-DAA. (A): 5–7 cm skin incision was placed in the lateral groin crease. (B): Femoral head was taken out through the minimally invasive incision. (C): A puncture incision with a length of about 1 cm was made at a distance of about 10 cm from the distal end of the horizontal incision through the muscle space with the “finger touch method”. A 10 mm diameter trocar was then

handle (Johnson & Johnson, USA). Finally, the anteversion and inclination were adjusted endoscopically (Fig. 2F-G). The acetabular prosthesis was pressed through the puncture point with modular handle until satisfactory.

The surgeon externally rotated the involved lower limb for the femoral preparation, adduction was performed, and the folding table was extended for 30–40° to provide a hyperextension position. An elevating retractor was inserted posterior to the greater trochanter to lift the femur for more extensive exposure. The medullary cavity was reamed according to the preoperative measurement (Fig. 2H). After

inserted into the puncture incision. (D-E): The acetabular preparation was performed endoscopically. (F-G): After the acetabular prosthesis was placed, the inclination and anteversion of the prosthesis were adjusted under the endoscopy. (H): The femoral preparation was performed with the aid of the elevating retractor. (I-J): The surgical scars of Endo-DAA after surgery and at postoperative 6 months

the length of the lower limbs, the stability of the prosthesis, the joint mobility, and the impingement phenomenon were checked by x rays and physical examination, the femoral stem prosthesis and femoral head were inserted.

**Bikini-DAA** In the Bikini-DAA group, the surgical operations were performed through a horizontal incision about 6–8 cm in length [19]. Neither the endoscopy nor the puncture incision was utilized.

In both groups, the joint capsule was sutured without the placement of drainage tubes and the wound was closed

with absorbable sutures by the standard layered manner [19] (Fig. 2I).

### Perioperative interventions

All patients received the same standardized treatment before and after surgery, including pain management and rehabilitation protocols [20]. In addition, all patients received weight-adjusted prophylactic antibiotics and thrombosis prophylaxis [21]. Patients can begin quadriceps isometric contraction training and ankle flexion and extension activities after the operation. On the day of the operation, patients are encouraged to get up and start weight-bearing exercise.

### Radiographic measurements

The cup inclination was measured on postoperative anteroposterior pelvic radiographs, that is, the angle between the line connecting the ischial tubercles and the line passing through the ellipse described by the acetabular cups [22]. The inverse trigonometric function ( $\arcsin(D1/D2)$ ) of the ratio of the length of the major axis (D1) to the minor axis (D2) of the ellipse matching the partial edge of the acetabulum was used to calculate the cup anteversion [23]. Appropriate anteversion was defined as  $15^\circ (\pm 10^\circ)$  and inclination was defined as  $40^\circ (\pm 10^\circ)$  (Lewinneck's safe zone) [24]. The leg length discrepancy (LLD), the difference in the vertical distance between the straight line through the two teardrop points and the corresponding tips of the lesser trochanter of the femur on both sides, was measured on the anteroposterior pelvic radiographs [25]. All measurements were done by two experienced surgeons and the average of the two measurements was taken as the final value.

### Clinical measurements

Perioperative data including operating time, incision length, blood loss, and length of stay were collected. The patients presented to the outpatient department for routine follow-up at 3, 6, 12 months, and then followed up once a year. Evaluation measures included postoperative complications, Harris hip score (HHS) [26] and forgotten joint score (FJS). The FJS is a 12-question questionnaire designed to measure patient satisfaction. Scores are added and converted to a 100-point scale, with higher scores representing higher satisfaction and results [27]. At 6 months after surgery, scar cosmesis assessment and rating(scar) scale was used to evaluate the aesthetic appearance of scars [28] (Fig. 2J). The scale is scored on a scale of 0 to 15, with 0 indicating the best scar outcome and 15 indicating the worst scar outcome. Besides, the patient's satisfaction with the scar's appearance

(very satisfied, satisfied, unsatisfied, or very unsatisfied) was also recorded [21].

### Complications

We also analyzed the occurrence rate of various adverse events after surgery. Complications included LFCN injury (defined as numbness of the nerve area innervated by LFCN), wound dehiscence, delayed wound healing (defined as non-healing of the wound at 2 weeks after surgery), thigh pain (visual analogue scale  $\geq 3$ ), deep infection, venous thrombosis, pulmonary embolism, prosthesis loosening, periprosthetic fracture, hip dislocation, and any adverse events need for return surgery. Deep infection was defined as a bacterial breach of a deeper layer (tensor fascia latae), also known as a prosthetic joint infection (PJI).

### Data analyses

All analyses were performed using SPSS 25.0 (IBM, USA) statistical software package. continuous variable data were expressed as mean and standard deviation (SD) or range, while categorical variables were expressed as frequencies or percentages. Kolmogorov-Smirnov test was used for normality of continuous variables. For comparison between groups, independent sample t test was used if continuous variables met normality, otherwise, Mann-Whitney U test was used. Fisher's exact test was used for categorical variables. Repeated-measures analysis of variance was performed to define the differences at different time points within the group. All tests were bilateral. When  $p < 0.05$ , the difference was considered statistically significant.

## Results

### Demographic data

As shown in Fig. 1, a total of 443 patients initially completed the Endo-DAA, but ultimately 419 patients met the inclusion criteria. Of these, 17 patients were lost to follow-up, and 195 hips in the Endo-DAA group and 207 hips in the Bikini-DAA group were reported and entered the stage of data analysis. As shown in Table 1, there were no significant differences in demographic or clinical characteristics between the two groups. All patients were followed up for more than 1 year.

### Surgical variables and radiographic measurements

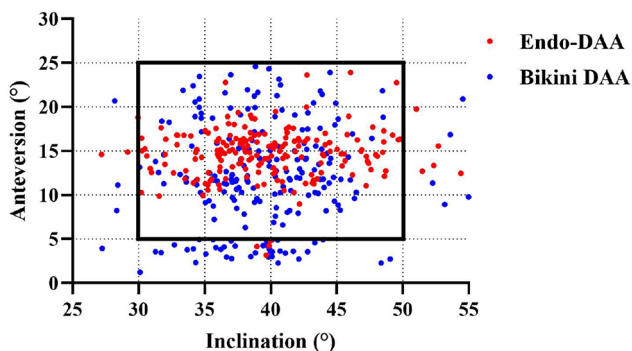
The results showed that operation time ( $64.7 \pm 11.9$  vs.  $83.1 \pm 14.2$  min), blood loss ( $155.2 \pm 31.6$  vs.



**Table 1** Demographics of patients

	Endo-DAA group (n=195)	Bikini-DAA group (n=207)	P value
Number of patients	195	207	
Age(years)[Mean ± SD]	60.9 ± 10.8	61.5 ± 13.3	0.621
Gender(Male/Female)	96/99	108/99	0.555
Side(left/right)	98/97	101/106	0.769
BMI (kg/m <sup>2</sup> ) [Mean (Range)]	23.9 ± 2.7 (1.1–5.0)	23.4 ± 2.8 (1.0–5.0)	0.069
Diagnoses			0.981
Osteoarthritis	19	21	
Posttraumatic arthritis	21	25	
Fractures	46	43	
Avascular necrosis	86	95	
Rheumatoid arthritis	13	12	
Sequela of developmental hip dysplasia	10	11	
Mean Follow-Up (Years) [Mean (Range)]	3.0 (1.1–5.0)	3.1 (1.0–5.0)	

Abbreviation BMI Body mass index



**Fig. 3** Scatterplot of acetabular component alignment in both groups. Square box reflects the “safe zone”

**Table 2** Surgical variables and radiographic measurements between the two groups

Outcomes	Endo-DAA group (n=195)	Bikini-DAA group (n=207)	P value
Operating time (min)	64.7 ± 11.9	83.1 ± 14.2	<0.001
Estimated blood loss (ml)	153.2 ± 31.6	164.1 ± 34.9	0.001
Incision length (cm)	5.4 ± 0.6	7.0 ± 0.9	<0.001
Length of stay (day)	2.4 ± 1.3	4.1 ± 1.6	<0.01
Cup inclination (°)	39.5 ± 5.2	38.9 ± 4.9	0.234
Within the “safe zone” (n)	188(96.4%)	198(95.7%)	0.698
Cup anteversion (°)	14.7 ± 2.2	12.1 ± 3.4	<0.001
Within the “safe zone” (n)	191(97.9%)	167(80.7%)	<0.001
Leg-length discrepancy (mm)	1.1 ± 3.5	1.2 ± 3.0	0.758

164.1 ± 34.9 ml), incision length (5.4 ± 0.6 vs. 7.0 ± 0.9) and hospital stay (2.4 ± 1.3 vs. 4.1 ± 1.6) in Endo-DAA group were significantly lower than those in bikini-DAA group (all P < 0.05).

**Table 3** Comparison of the duration to start no-assistive-device walking between all groups

Postoperative time	Endo-DAA group (n=195)	Bikini-DAA group (n=207)	<0.001
< 12 h	189(96.9%)	97(46.9%)	
12–24 h	6(3.1%)	105(50.7%)	
> 24 h	0	5(2.4%)	

**Table 4** Clinical outcomes at different follow-up time points between groups

Outcomes	Endo-DAA group (n=195)	Bikini-DAA group (n=207)	P value
HHS			
Before operation	36.3 ± 13.0	35.1 ± 13.4	0.363
6 weeks	78.8 ± 11.3	67.1 ± 10.2	<0.001
6 months	85.4 ± 8.4	86.5 ± 8.1	0.182
12 months	93.4 ± 6.4	93.7 ± 5.4	0.611
FJS			
6 weeks	62.6 ± 18.2	54.2 ± 18.0	<0.001
6 months	71.2 ± 17.4	72.9 ± 16.8	0.320
12 months	84.4 ± 13.9	83.6 ± 14.6	0.574

Abbreviation HHS Harris Hip Score, FJS Forgotten Joint Score

Radiographic analysis of the prosthesis showed that the cup anteversion in the Endo-DAA group was significantly better than that in the Bikini-DAA group (14.7 ± 2.2 vs. 12.1 ± 3.4, P < 0.001), and the proportion of cup anteversion within the “Lewinneck safe zone” in the Endo-DAA group was also significantly higher than that in the Bikini-DAA group (Fig. 3). There was no significant difference in cup inclination between the two groups. The absolute value of LLD exceeded 7 mm in none of the patients. (See Table 2 for details).

**Functional outcomes**

The time for Endo-DAA group to start no-assistive-device walking was significantly shorter than that for Bikini-DAA group (P < 0.001, Table 3). In the Endo-DAA group, 96.9% patients started no-assistive-device walking within 12 h after surgery. In the Bikini DAA group, only 46.9% of patients started no-assistive-device walking within 12 h after surgery. As shown in Table 4, HHS and FJS of all patients significantly improved after surgery compared with those before surgery. At the early postoperative follow-up, the Endo-DAA group had significantly better HHS (78.8 ± 11.3 vs. 67.1 ± 10.2, P < 0.001) and FJS (62.6 ± 18.2 vs. 54.2 ± 18.0, P < 0.001) than that in Bikini-DAA group. There was no significant difference between the two groups at 6 months and 12 months follow-up. At 1 year follow-up, HHS of Endo-DAA group and Bikini-DAA group also reached 93.4 ± 6.4 and 93.7 ± 5.4 points respectively, and

FJS also reached  $84.4 \pm 13.9$  points and  $83.6 \pm 14.6$  points respectively.

### SCAR scores and satisfaction

At 6 months after surgery, patients in the Endo-DAA group had better SACR scores ( $5.8 \pm 1.5$  vs.  $7.6 \pm 1.9$ ,  $P < 0.001$ ). Meantime, a significantly higher proportion of patients in the Endo-DAA group were very satisfied or satisfied with the cosmetic aspects of the scars than that in the bikini-DAA group (96.9% vs. 82.6%,  $P < 0.001$ ) (Table 5).

### Complications

There were four hips in the Endo-DAA group (2.1%) and twelve hips in the Bikini-DAA group (5.8%) with related complications, and the incidence of total and minor complications was significantly lower in the Endo-DAA group than that in the Bikini group ( $P < 0.05$ ) (Table 6).

In the Endo-DAA group, one patient suffered a periprosthetic fracture (Vancouver A) due to a fall, which improved after conservative treatment. One hip with femoral neck fracture developed lower limb venous thrombosis after surgery, and the thrombosis disappeared after 4 weeks of oral anticoagulant accompanied by appropriate activities. In addition, one superficial wound infection was treated with antibiotics based on antibiogram. One Wound dehiscence occurred 2 days postoperatively, which healed after surgical debridement and antibiotic treatment. In the Bikini-DAA group, one recurrent dislocation was recorded one month postoperatively, and treated with reoperation. Deep vein thrombosis was found in two patients within 3 days after surgery, which recovered with adherence to anticoagulants. Besides, two superficial wound infection was recorded 3 days postoperatively, and treated with antibiotics. one patient with wound dehiscence was treated with disinfection daily, lasting for 2 weeks, and two cases of wound dehiscence were treated with debridement. One hematoma and one thigh pain (VAS  $\geq 3$  points) were relieved within 2 weeks. Furthermore, two LFCN dysesthesia (presented at 2 days) recovered 3 weeks later.

### Discussion

To the best of our knowledge, this is the first study to describe differences in radiographic and functional outcome between minimally invasive endoscopic DAA and Bikini-DAA in THA. With a mean follow-up of 3.0 years, compared with Bikini-DAA, Endo-DAA had a shorter length of incision, the operation time, the blood loss and postoperative hospital stay. Endo-DAA provides reliable prosthesis positioning

**Table 5** Comparison of SCAR scores and satisfaction levels between the two groups at 6 months

Degree	Endo-DAA group (n = 195)	Bikini-DAA group (n = 207)	P value
SCAR scores	$5.8 \pm 1.5$	$7.6 \pm 1.9$	< 0.001
Satisfaction with scar			< 0.001
Very satisfied	153	131	
Satisfied	36	40	
Unsatisfied	6	34	
Very unsatisfied	0	2	

Abbreviation SCAR Scar Cosmesis Assessment and Rating

**Table 6** Major and minor complications

Complications	Endo-DAA group (n = 195)	Bikini-DAA group (n = 207)	P value
Major complications			0.528
Prosthesis loosening	0	0	NA
Periprosthetic fracture	1	0	0.485
Dislocation	0	1	0.515
Deep Venous Thrombosis	1	2	0.522
Deep infection	0	0	NA
Reoperation	0	1	0.515
Minor complications			0.039
Superficial infection	1	2	0.522
Wound dehiscence	1	3	0.334
Thigh pain	0	1	0.515
Hematoma	0	1	0.515
LFCN dysesthesia	0	2	0.265
Total complications	4	12	0.046

Abbreviation LFCN lateral femoral cutaneous nerve

and hip reconstruction with better cup anteversion. Subsequently, Endo-DAA can start no-assistive-device walking within a shorter time after surgery and provide better HHS and FJS scores in the early postoperative period. Moreover, Endo-DAA provided better scar scores than Bikini-DAA, and Endo-DAA had a higher percentage of very satisfied or satisfied with the cosmetic aspects of the scars. Finally, Endo-DAA has a lower rate of minor complications.

To ensure rapid and early functional recovery with fewer complications, many minimally invasive techniques in THA have been rapidly developed [29]. The anterior approach enters the surgical site from the muscle space, with a small degree of muscle damage and a low incidence of complications making DAA increasingly popular [30]. However, Tissot et al. [31]. showed that compared with the posterior approach, standard longitudinal incisions with DAA are still associated with a higher incidence of infection complications and nerve injury. A systematic review also showed that the longitudinal incision of DAA was prone to form large scars in the later stage [32]. To prevent hypertrophic scarring and optimize cosmetic outcomes, Corten et al. [33] and Nizam et al. [19]. applied Bikini-DDA to THA patients

and achieved good clinical improvements. Therefore, the Bikini incision is a safe alternative to the traditional longitudinal incision [34]. But Di et al. [32] demonstrated that absolute complication rates were higher in the Bikini group compared to the DAA group. Besides, transverse incisions in Bikini-DAA is often at the same level or higher than the acetabulum and is not conducive for surgeon to acetabular preparation [32]. Consequently, it is an urgent problem to find an ideal surgical technique that can preserve Bikini's beautiful incision without damaging muscles and nerves and can reduce the incidence of the above complications.

In an effort to improve healing and cosmesis, a new surgical technique for DAA THA has been created. We found that the Endo-DAA technique was superior to Bikini-DAA in terms of patient blood loss, operative time, and hospital of stay. Similar to the conventional bikini incision, the main incision in Endo-DAA is placed at the lateral groin crease via the Langer's line avoiding any tension during healing. However, the difference is that the incision length is shorter in Endo-DAA ( $5.4 \pm 0.6$  vs.  $7.0 \pm 0.9$  cm). The smaller incision length, one of the innovations of Endo-DAA, allows the incision to avoid the groin crease. Since Bikini-DAA perform surgical procedures through the incision approach directly, a larger incision is required for better surgical exposure and more ideal alignment of the prosthesis components. In Endo-DAA, preparation of the acetabular side can be done by using a split tool under endoscopic monitoring. Thus, incisions in Endo-DAA are limited only by the size of the acetabular component.

Meantime, surgical scars in Endo-DAA are finer and more hidden. Therefore, a larger proportion of Endo-DAA patients were satisfied with scar appearance, and SCAR scores were significantly better. In Endo-DAA, the connecting rod can be entered through the puncture point to avoid iatrogenic damage to the soft tissues such as muscles for better visual field and operating space. We make the puncture incision by using the "finger touch method" from the inside out. Our puncture incision is made through the muscle space without cutting the muscle, so this technique can relatively further reduce the damage for muscle. Above advantages also helped patients achieve better functional scores at an early stage.

Our results suggest that Endo-DAA can achieve credible prosthetic location and better cup anteversion. Compared with the DAA reported by Verhaegen et al. [35], which showed an increasing trend of inclination and anteversion, Endo-DAA was also relatively better. In this study, the Endo-DAA also has a higher percentage of anteversion within the "Lewinneck safe zone". While the bikini approach requires the use of an eccentric instrument, we used the Endo-DAA from an endoscopically assisted incision, and preparation of the acetabular side can be done using a split-type tool

through the distal puncture under endoscopic monitoring. In addition, Endo-DAA provides the surgeon with a better position of the acetabular prosthesis under the field of view provided by the endoscope. A good surgical vision can provide a relatively short learning curve for beginners. Bikini-DAA has a longer learning curve because of its minimally invasive incision and the use of eccentric device. The Endo-DAA also avoids the challenge of excessive cup inclination and anteversion angle that would be caused by the bikini approach.

Endo-DAA has a higher functional score in the early stage, which helps patients return to life more quickly. Meantime, the higher FJS of Endo-DAA in the early stage can also convince patients that this is a natural, forgotten artificial joint. FJS presents patients' subjective feelings by assessing the extent to which patients forget the existence of artificial prostheses in daily life [36], and it has been verified in THA patients with good reliability and validity [37]. At early follow-up, FJS in Endo-DAA group exceeded 60 points. These results were better than the FJS of Zhang et al. [38] in the early FJS after conventional DAA ( $50.78 \pm 7.57$ ). The reason why Endo-DAA enables patients to forget this is an artificial joint prosthesis early on, we think that in addition to the fact that we apply the smallest possible minimally invasive incision and less soft tissue damage. During the femoral preparation, the continuous use of the hook and retractor in Bikini-DAA to fully expose the proximal femur also caused muscle damage. However, the proximal femur was exposed with the proximal femur lifting device in Endo-DAA, which provided a reliable fulcrum for the preparation of femoral reaming and the implantation of prosthesis, thus reducing the difficulty of operation and avoiding the influence on muscles. Furthermore, satisfactory scarring can enable patients to achieve the purpose of accelerated recovery, can enable patients to return to life and work earlier, and help patients feel that this is a natural joint.

In addition, there was no LFCN injury in Endo-DAA group. Conventional DAA has a longer incision, which is prone to damage the lateral branch of LFCN [39]. One of the reasons that Endo-DAA has an advantage in LFCN may be that we carefully limited the incision length outside the perpendicular line of the anterior superior iliac spine to more than two thirds of the total incision length to protect LFCN from direct trauma [21]. Simultaneously, the LFCN injury seems to be a reversible sensory disturbance caused by the pressure of the retractor, rather than an irreversible injury caused by the detachment. In Endo-DAA, we can perform the procedure on the acetabular side under endoscopy without the need for retractors to expose the field of view. Thus, Endo-DAA avoids direct and indirect damage to LFCN.

In summary, we provide an endoscopy assisted minimally invasive surgical technique in THA with less interference to

the muscles and nerves and a shorter incision length compared to the bikini DAA. Our outcomes also indicated that Endo-DAA can provide an alternative minimally invasive THA surgical technique with fewer complications and favorable clinical and radiological outcomes. This technique has also facilitated the development of minimally invasive surgery in THA.

The study still has some shortcomings. First, Endo-DAA requires a learning curve and special instruments, including assisted endoscopic system and a specially designed split-type tool; Second, the number of patients enrolled is still relatively small, which may jeopardise the capability to identify the complications with low incidence; Third, this study lacks comparison with other more extensive THA surgical methods, such as conventional DAA or posterolateral; Finally, Endo-DAA is not suitable for revision hip replacement and complex hip dysplasia, The indication is also similar to that for Bikini-DAA [12, 40]. In the future, the authors intend to prospectively include more patients and compare them with other more THA surgical techniques.

## Conclusion

Endo-DAA, as a new minimally invasive surgical technique for THA, improves patients' subjective satisfaction with scar aesthetics, accelerates rapid recovery of postoperative function, and reduces postoperative complications compared with Bikini-DAA.

**Acknowledgements** Not applicable.

**Author contributions** Zhibo Deng and Hanhao Dai drafted the manuscript. Zhibo Deng and Chao Song collected the data. Fenqi Luo and Rongsheng Zhang analyzed the data. Yijing Wu made the figure and tables. Jie Xu and Jun Luo contributed to the manuscript preparation. All authors contributed to refining the ideas, carrying out additional analyses and finalizing this paper. All authors approved the final manuscript and the submission to this journal.

**Funding** This work was supported by the the Firestone Research Project of Fujian Provincial Hospital (2020029HSJJ), the Fujian Provincial Natural Science Foundation Projects (2020J05270), the Medical Innovation Project of Fujian Provincial Health Department (2020QNA009), the Major Scientific Research Project of Fujian Province (2021ZD01003) and the Fujian Provincial Natural Science Foundation Projects (2021J01376).

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

## Declarations

**Ethical approval and consent to participate** This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Fujian Provincial Hospital

(No. K2020-12-019). Informed consent was obtained from individual participants and/or their legal guardians in the study. Besides, the accessed patient data complied with relevant protection, privacy guidelines and regulations.

**Consent for publication** Not applicable.

**Conflict of interest** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

## References

- Andreyeva T, Sturm R, Ringel JS (2004) Moderate and severe obesity have large differences in health care costs. *Obes Res* 12(12):1936–1943. <https://doi.org/10.1038/oby.2004.243>
- Ferguson RJ, Palmer AJ, Taylor A, Porter ML, Malchau H, Glyn-Jones S (2018) Hip replacement. *Lancet* 392(10158):1662–1671. [https://doi.org/10.1016/s0140-6736\(18\)31777-x](https://doi.org/10.1016/s0140-6736(18)31777-x)
- Patel N, Golwala P (2023) Approaches for total hip arthroplasty: a systematic review. *Cureus* 15(2):e34829. <https://doi.org/10.7759/cureus.34829>
- Anderson CG, Jang SJ, Brilliant ZR et al (2023) Complication rate after primary total hip arthroplasty using the posterior Approach and Enabling Technology: a consecutive series of 2,888 hips. *J Arthroplasty* 38(7s):S119–S. 123.e113
- Banasiak S, Hartel M, Frosch KH, Berger-Groch J (2024) Post-operative lymphedema after primary total hip arthroplasty: prospective analysis of bikini incision-type direct anterior approach versus established standard approaches. *J Orthop Surg Res* 19(1):54. <https://doi.org/10.1186/s13018-023-04525-7>
- von Hertzberg-Boelch S, Mueller L, Stratos I, Arnholdt J, Holzapfel B, Rudert M (2023) Which patient-specific parameters correlate with operation time for total hip arthroplasty? - a retrospective analysis of the direct anterior approach. *Int Orthop* 47(8):1975–1979. <https://doi.org/10.1007/s00264-023-05841-7>
- Ponziani L, Di Caprio F, Tentoni F, Grana S, Di Meo A, Gigli M (2021) Anterior and antero-lateral mini-invasive approaches for primary total hip replacement. *Acta Biomed* 92(S3):e2021014. <https://doi.org/10.23750/abm.v92iS3.11704>
- Zhao HY, Kang PD, Xia YY, Shi XJ, Nie Y, Pei FX (2017) Comparison of early functional recovery after total hip arthroplasty using a Direct Anterior or Posterolateral Approach: a Randomized Controlled Trial. *J Arthroplasty* 32(11):3421–3428. <https://doi.org/10.1016/j.arth.2017.05.056>
- Yang Z, Feng S, Guo KJ, Zha GC (2021) Patient-reported results of simultaneous direct anterior approach and posterolateral approach total hip arthroplasties performed in the same patients. *J Orthop Traumatol* 22(1):46. <https://doi.org/10.1186/s10195-021-00611-w>
- Leunig M, Faas M, von Knoch F, Naal FD (2013) Skin crease 'bikini' incision for anterior approach total hip arthroplasty: surgical technique and preliminary results. *Clin Orthop Relat Res* 471(7):2245–2252. <https://doi.org/10.1007/s11999-013-2806-0>
- Leunig M, Huttmacher JE, Ricciardi BF, Impellizzeri FM, Rüdiger HA, Naal FD (2018) Skin crease 'bikini' incision for the direct anterior approach in total hip arthroplasty: a two- to four-year comparative study in 964 patients. *Bone Joint J* 7100–b. <https://doi.org/10.1302/0301-620x.100b7.Bjj-2017-1200.R2>
- Jin X, Chen G, Chen M et al (2023) Comparison of postoperative outcomes between bikini-incision via direct anterior approach and posterolateral approach in simultaneous bilateral total hip



- arthroplasty: a randomized controlled trial. *Sci Rep* 13(1):7023. <https://doi.org/10.1038/s41598-023-29146-2>
13. Burnham RR Jr, Kiernan H, Ortega LF et al (2022) Defining the learning curve of Anterior Total Hip Arthroplasty after Fellowship-specific training. *J Am Acad Orthop Surg* 30(1):e131–e138. <https://doi.org/10.5435/jaaos-d-21-00232>
  14. de Steiger RN, Lorimer M, Solomon M (2015) What is the learning curve for the anterior approach for total hip arthroplasty? *Clin Orthop Relat Res* 473(12):3860–3866. <https://doi.org/10.1007/s11999-015-4565-6>
  15. Hallert O, Li Y, Brismar H, Lindgren U (2012) The direct anterior approach: initial experience of a minimally invasive technique for total hip arthroplasty. *J Orthop Surg Res* 7:17. <https://doi.org/10.1186/1749-799x-7-17>
  16. Dai H, Deng Z, Yang L, Orthop et al (2024) <https://doi.org/10.1111/os.14015>
  17. Luo J, Xu J, Chen YC et al (2021) [Short-term efficacy of endoscope assisted arthroplasty for total hip replacement via a minimum invasive direct anterior approach]. *Zhonghua Yi Xue Za Zhi* 101(27):2164–2169. <https://doi.org/10.3760/cma.j.cn112137-20201202-03253>
  18. Cuschieri S (2019) The STROBE guidelines. *Saudi J Anaesth* 13(Suppl 1):S31–s34. [https://doi.org/10.4103/sja.SJA\\_543\\_18](https://doi.org/10.4103/sja.SJA_543_18)
  19. Nizam I, Dabirrahmani D, Alva A, Choudary D (2022) Bikini anterior hip replacements in obese patients are not associated with an increased risk of complication. *Arch Orthop Trauma Surg* 142(10):2919–2926. <https://doi.org/10.1007/s00402-021-04143-0>
  20. Husted H, Lunn TH, Troelsen A, Gaarn-Larsen L, Kristensen BB, Kehlet H (2011) Why still in hospital after fast-track hip and knee arthroplasty? *Acta Orthop* 82(6):679–684. <https://doi.org/10.3109/17453674.2011.636682>
  21. Wang Q, Yue Y, Yang Z, Chen L, Li Q, Kang P (2021) Comparison of postoperative outcomes between traditional longitudinal incision and Bikini Incision in Total Hip Arthroplasty via Direct Anterior Approach: a Randomized Controlled Trial. *J Arthroplasty* 36(1):222–230. <https://doi.org/10.1016/j.arth.2020.07.047>
  22. Ackland MK, Bourne WB, Uhthoff HK (1986) Anteversion of the acetabular cup. Measurement of angle after total hip replacement. *J Bone Joint Surg Br* 68(3):409–413. <https://doi.org/10.1302/0301-620x.68b3.3733807>
  23. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR (1978) Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 60(2):217–220
  24. Song X, Ni M, Li H et al (2018) Is the cup orientation different in bilateral total hip arthroplasty with right-handed surgeons using posterolateral approach? *J Orthop Surg Res* 13(1):123. <https://doi.org/10.1186/s13018-018-0789-y>
  25. Heaver C, St Mart JP, Nightingale P, Sinha A, Davis ET (2013) Measuring limb length discrepancy using pelvic radiographs: the most reproducible method. *Hip Int* 23(4):391–394. <https://doi.org/10.5301/hipint.5000042>
  26. Daliri M, Moallem SMH, Sadeghi M et al (2023) Clinical outcomes and complications following Hip Fusion Conversion to total hip arthroplasty: a systematic review and Meta-analysis. <https://doi.org/10.1016/j.arth.2023.07.021>
  27. Singh V, Zak S, Schwarzkopf R, Davidovitch R (2020) Forgotten joint score in THA: comparing the Direct Anterior Approach to posterior Approach. *J Arthroplasty* 35(9):2513–2517. <https://doi.org/10.1016/j.arth.2020.04.074>
  28. Kantor J (2017) Reliability and Photographic Equivalency of the scar Cosmesis Assessment and Rating (SCAR) Scale, an Outcome measure for postoperative scars. *JAMA Dermatol* 153(1):55–60. <https://doi.org/10.1001/jamadermatol.2016.3757>
  29. Obando DV, Gallego KJ, Gonzalez S, Álvarez AG, Bautista M, Sánchez-Vergel A (2023) Results of the transition from posterolateral to anterior minimally invasive approach for total hip arthroplasty. *J Orthop Surg Res* 18(1):816. <https://doi.org/10.1186/s13018-023-04291-6>
  30. Rogers N, Rullán PJ, Pasqualini I et al (2024) Lower 90-day inpatient readmission and 1-year reoperation in patients undergoing robotic versus manual total hip arthroplasty through an anterior approach. *Technol Health Care* <https://doi.org/10.3233/thc-231646>
  31. Tissot C, Vautrin M, Luyet A, Borens O (2018) Are there more wound complications or infections with direct anterior approach total hip arthroplasty? *Hip Int* 28(6):591–598. <https://doi.org/10.1177/1120700018759617>
  32. Butler J, Singleton A, Miller R, Morse B, Naylor B, DeCook C (2022) Bikini Incision vs longitudinal incision for anterior total hip arthroplasty: a systematic review. *Arthroplast Today* 17:1–8. <https://doi.org/10.1016/j.artd.2022.06.010>
  33. Corten K, Holzapfel BM (2021) Direct anterior approach for total hip arthroplasty using the bikini incision. *Oper Orthop Traumatol* 33(4):318–330. <https://doi.org/10.1007/s00064-021-00721-y>
  34. Di Martino A, Brunello M, Rossomando V et al (2023) Aesthetic results, functional outcome and Radiographic Analysis in THA by Direct Anterior, Bikini and Postero-lateral Approach: is it worth the Hassle? *J Clin Med* 12(3). <https://doi.org/10.3390/jcm12031072>
  35. Verhaegen JCF, Wei R, Kim P, Beaulé PE, Corten K, Grammatopoulos G (2022) The Safety and Efficacy of the Anterior Approach Total Hip Arthroplasty as per body Mass Index. <https://doi.org/10.1016/j.arth.2022.08.021>
  36. Rosinsky PJ, Chen JW, Lall AC, Shapira J, Maldonado DR, Domb BG (2020) Can we help patients forget their Joint? Determining a threshold for successful outcome for the Forgotten Joint score. *J Arthroplasty* 35(1):153–159. <https://doi.org/10.1016/j.arth.2019.08.014>
  37. Sansone V, Fennema P, Applefield RC et al (2020) Translation, cross-cultural adaptation, and validation of the Italian language Forgotten Joint Score-12 (FJS-12) as an outcome measure for total knee arthroplasty in an Italian population. *BMC Musculoskelet Disord* 21(1):23. <https://doi.org/10.1186/s12891-019-2985-2>
  38. Zhang B, Liu S, Liu Z et al (2022) Clinical and radiologic outcomes in patients undergoing primary total hip arthroplasty with Collum Femoris Preserving stems: a comparison between the direct anterior approach and the posterior approach. *BMC Musculoskelet Disord* 23(1):77. <https://doi.org/10.1186/s12891-022-05040-2>
  39. Rudert M, Horas K, Hoberg M et al (2016) The Wuerzburg procedure: the tensor fasciae latae perforator is a reliable anatomical landmark to clearly identify the Hueter interval when using the minimally-invasive direct anterior approach to the hip joint. *BMC Musculoskelet Disord* 17:57. <https://doi.org/10.1186/s12891-016-0908-z>
  40. Sang W, Xue S, Xu Y, Liu Y, Zhu L, Ma J (2021) Bikini Incision increases the incidence of lateral femoral cutaneous nerve Injury in Direct Anterior Approach hip arthroplasty: a prospective Ultrasonic, electrophysiological, and clinical study. *J Arthroplasty* 36(10):3463–3470. <https://doi.org/10.1016/j.arth.2021.05.012>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.