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Correlation Analysis of Limb Length Differences and Surgical Approaches Following Unilateral Total Hip Arthroplasty

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Abstract: *Aim:* This research aims to analyze the transition from the posterolateral approach (PLA) to the direct anterior approach (DAA) in 101 cases of unilateral total hip arthroplasty (THA). In addition, the study specifically aims to evaluate limb length discrepancy (LLD). *Methods:* We conducted a retrospective analysis of 101 patients who had unilateral THA from September 2021 to August 2024. The causes of THA included femoral neck fracture (n = 28), osteoarthritis (n = 23), osteonecrosis of the femoral head (n = 25), and developmental dysplasia of the hip (n = 25). The mean age was 61.50 years in the PLA group and 63.00 years in the DAA group. Safety feasibility was assessed by analyzing procedure time, incision length, and bleeding volume. LLD was indirectly evaluated by measuring the difference in central edge angles of the postoperative pelvic orthotopic plate. This was done to assess the superiority of the DAA. *Results:* The DAA group had a longer operation time, less blood loss, and a shorter incision length compared to the PLA group, with a statistically significant difference ($P < 0.05$). Additionally, body mass index was found to be linearly correlated with operation length. The LLD in the DAA group was significantly smaller than that in the PLA group ($P < 0.05$). Moreover, this LLD was linearly associated with the difference in the central edge angle. *Conclusion:* DAA may effectively control LLD after THA, resulting in less blood loss and shorter incisions, though it may require longer operative time.

Keyword: Total hip arthroplasty; Limb length discrepancy; Posterolateral approach; Direct anterior approach

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1. Introduction

Total hip arthroplasty (THA) is a surgical procedure that replaces the hip joint with artificial implants. It is suitable for treating osteoarthritis, necrosis of the femoral head, femoral neck fracture, rheumatoid arthritis, traumatic arthritis, bone tumors, ankylosing spondylitis, and other diseases [1]. Limb length discrepancy (LLD) is one of the most common complications following primary THA. Contributing factors include individual variations in femoral morphology, inappropriate selection of the preoperative prosthesis, inadequate release of osteotomy and soft tissue, imprecise prosthesis placement, and challenges in controlling muscle relaxation during various anesthesia methods [2]. Limb shortening after THA is relatively rare compared to limb lengthening. Several common reasons contribute to this phenomenon: (1) a preoperative true LLD greater than 40 mm may lead to incomplete correction; (2) a limb that is only slightly lengthened can easily damage blood vessels and nerves; (3) excessive acetabular filling and upward movement can exacerbate the issue; and (4) postoperative cement subsidence of the cemented prosthesis may result in limb shortening [3-5]. Previous clinical data suggest that LLD greater than 20 mm can cause postural pelvic tilt [6], while LLD greater than 10 mm may lead to new-onset low back pain after surgery [7]. In contrast, LLD less than 10 mm typically allows for compensation within three months, as the range of motion (ROM) of the unoperated hip improves [8]. It is generally accepted that an LLD of 10 mm may serve as a cut-off value for assessing whether compensation occurs in the contralateral limb [9]. Reducing LLD to less than 5 mm in patients with ankylosing spondylitis significantly improves clinical outcomes after hip arthroplasty, making it a more accurate target than the current standard of less than 10 mm [10]. Although LLD less than 7 mm is considered a reasonable threshold for reducing residual discomfort after THA [11], patients with radiographic LLD (R-LLD) less than 5 mm and longer perceived LLD (P-LLD) over one year still report poor Forgotten Joint Score (FJS-12) outcomes [12].

The surgical approaches for THA include the direct anterior approach (DAA), the direct lateral approach (DLA), the anterolateral approach (ALA), and the posterolateral approach (PLA). Although the traditional THA approach, represented by PLA, achieves remarkable anatomical results, it can also lead to muscle injuries around the joint, resulting in soft tissue release and a heightened risk of dislocation after surgery [13]; to prevent early postoperative dislocation, surgeons may implement compensatory measures on the femoral side, as previously mentioned [14]. For example, a larger femoral head can improve the head-to-neck ratio, thereby increasing the ROM before the initial impact point and reducing the dislocation rate [15]. However, inaccurate repairs of the acetabular position or lower LLD do not independently increase the risk of dislocation [16]. Additionally, increasing limb length does not reduce the likelihood of late dislocation associated with neurological diseases or muscle tension. For patients at a higher risk of postoperative dislocation, it is recommended to use a femoral component with a lower neck angle (larger offset) to lower this risk [17].

The DAA for THA is a minimally invasive surgical technique that provides faster recovery, less pain, and a lower postoperative dislocation rate compared to other methods, leading to a surge in research [18,19]. However, less experienced joint surgeons may still face significant challenges, such as neurological dysfunction and intraoperative femur fractures [13]. DAA utilizes a midplane positioned between the tensor fascia latus, gluteus medius, sartorius, and rectus femoris, which helps to avoid the superior gluteal and femoral nerves. Despite this, injury to the lateral cutaneous femoral nerve (LCFN) is a common mild complication that is often reported only when patients are directly asked about their skin sensitivity. Anatomical studies have shown that around 70% of LFCN display a sartorius-type branching pattern. To minimize the risk of injury to the LFCN branch, a skin incision should be made 2 cm lateral to the anterior superior iliac spine (ASIS) and extended distally [20]. The difficulty of exposing the femur with the DAA approach increases the risk of intraoperative fracture. While a short shaft component can help reduce this risk [21], a longer stem can effectively guide the pull direction and prevent improper contact with the femoral cortex. This helps to minimize stress concentration in the proximal femur [22].

Previous studies have indicated that ALA may be more effective than PLA in managing postoperative LLD following THA [23]. However, few studies have compared the DAA with the PLA in this area. To this end, we conducted a three-year retrospective study evaluating data from 101 patients who underwent unilateral THA. Our goal was to assess the safety and feasibility of joint surgeons transitioning from the PLA to the DAA. Additionally, we aimed to evaluate the latter's effectiveness in controlling postoperative limb length differences.

2. Materials and methods

2.1. General information

In accordance with the Declaration of Helsinki, this study ensured compliance with established ethical standards. We conducted a retrospective analysis of data from 101 patients, including 49 males and 52 females, who received unilateral THA using either the DAA or the PLA between September 2021 and August 2024. The inclusion criteria were as follows: (1) a preoperative diagnosis of a femoral neck fracture, hip osteoarthritis, osteonecrosis of the femoral head (ONFH), or developmental dysplasia of the hip (DDH); (2) meeting the criteria for THA and having undergone unilateral THA for the first time; (3) aged between 25 and 80 years; (4) patients from the same surgical group. The exclusion criteria were as follows: (1) individuals with osteoporosis, cancer, or abnormal muscle and ligament function; (2) those with venous thrombosis or other factors that could raise the preoperative venous thromboembolism score; (3) individuals who have had major surgery in the past month; (4) those with contraindications to surgery or anesthesia. **Table 1** demonstrates that the statistical data sets were comparable ($P > 0.05$).

Table 1. Demographics and baseline characteristics of included cases

Characteristics		PLA (n = 48)	DAA (n = 53)	P
Age (y)		61.50 (53–74)	63.00 (52–72)	0.989
Gender (male/female)		23/25	26/27	0.909
BMI		27.12 ± 4.76	26.98 ± 4.55	0.881
Surgical side (left/right)		24/24	28/25	0.932
Diagnosis	Femoral neck fracture	13	15	0.947
	Hip osteoarthritis	10	13	
	ONFH	13	12	
	DDH	12	13	

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach; BMI: Body mass index; ONFH: Osteonecrosis of the femoral head; DDH: Developmental dysplasia of the hip

2.2. Surgical methods

All procedures were carried out by a highly experienced surgical team to minimize the risk of LLD after THA [24].

PLA-THA: The patient was in the lateral position. The surgical area was routinely disinfected and then covered with an aseptic surgical towel and skin envelope. A posterolateral incision was made in the hip joint. The skin and subcutaneous tissue were cut, followed by cutting the greater trochanteric capsule and fascia lata. The gluteus maximus was split, the outer spinor muscle group was cut, and the posterior joint capsule was exposed. After making a U-shaped incision in the joint capsule, yellow fluid was observed in the joint cavity and pathological changes of the femoral head were noticed along with dislocation. The femoral neck was truncated 1 cm along the lesser trochanter of the femur, and the femoral head was removed. The soft tissue in the acetabulum was cleaned before filing the acetabular component. The acetabular component was placed and consolidated with a 15-degree forward tilt and 45-degree outward angle, and the ceramic lining was placed after flushing. A 36 mm standard femoral head was tested to check the position and tightness, with no signs of dislocation, to reset the hip joint. The incision was washed thoroughly, the joint capsule and posterior muscle group were repaired, and the gauze was counted. The incision was then closed layer by layer, a drain tube was placed, and the area was wrapped sterilely.

DAA-THA: The patient was positioned horizontally. The surgical area was disinfected, aseptic surgical towels were placed, and the skin envelope was secured. The DAA approach was utilized to incise the skin and subcutaneous tissue, and the fascia muscularis of tensor fasciae latae was cut, allowing the tensor fasciae latae to be pulled outward. This fully exposed the rectus femoris space beneath, providing access to the ascending branch of the free lateral femoral artery for ligation and hemostasis. Cutting the joint capsule reveals pathological changes at the junction of the femoral head and neck. This procedure allows the identification of the saddle area and small nodules to determine the osteotomy line. The surgeon performed a femoral neck osteotomy, removed the femoral head, and cleaned the soft tissue, glenoid labrum, and some osteophytes in the acetabulum. The acetabulum was filed until uniform bleeding was achieved. The acetabular cup was then positioned at an angle of 15 degrees of abduction and 40 degrees of anteversion, secured with two 2-mm screws, and firmly placed ceramic lining. Shuck-test and Drop-test were qualified. The operating bed was adjusted to an inverted position of 30 degrees, providing a clear view of the proximal femur. The femoral bone marrow cavity was treated with a specialized file, and tests were performed on both the prosthetic handle and the femoral head (32 + 6 mm). The intraoperative fluoroscopic prosthesis was correctly placed and showed no signs of dislocation. The marrow cavity was drained, and the prosthesis handle was inserted into the bone marrow cavity. Subsequently, a 32 + 6 mm ceramic artificial femoral head prosthesis was installed, and the hip joint was reset without any evidence of dislocation. The incision was washed thoroughly, the joint capsule and fascia muscularis of the tensor fasciae latae were repaired, and the gauze was counted. The incision was then closed layer by layer, a drain tube was placed, and the area was wrapped sterilely.

2.3. Observation indexes

2.3.1. Perioperative index

Surgical time, total blood loss, and incision length are defined as follows: Surgical time is the duration from the initial skin incision to the completion of wound closure; total blood loss includes both blood lost during surgery and the amount of blood drained afterward; and incision length refers to the length of the surgical cut made in the skin.

2.3.2. Postoperative radiographic index

In this retrospective study, we measured the height difference at the center of rotation by using pelvic normotopia X-ray to indirectly evaluate LLD. The pelvic reference points consist of the teardrop-shaped structures and the ischium. We aimed to eliminate the influence of pelvic factors on LLD by aligning specific anatomical landmarks on X-ray film, these landmarks include the lines drawn between the lower edge of the tear and the lower edge of the ischium of both acetabula. Patients were enrolled in the study if the two lines were parallel. Since all enrolled patients underwent unilateral THA, our method for quantitative assessment of LLD was defined as subtracting the height of the contralateral rotation center from the height of the intraoperative rotation center.

An increase in the central edge angle is a crucial indicator of postoperative LLD [25], therefore the difference between the two center-edge angles was measured to explore the degree of correlation. The measurement method was performed as follows: When a circle overlaps the edge of the acetabular component, its center corresponds to the operative hip; similarly, if the opposite side overlaps the edge of the femoral head, its center corresponds to the opposite hip. To find the height of the center of rotation, measure the vertical distance from the hip joint's center of rotation to the lower edge of the teardrop on both sides. The center of rotation of the hip joint is similar to the center of the femoral head. Therefore, a vertical line is drawn from this center to measure the central edge angle, which is the angle between this vertical line and the outer upper edge of the acetabulum.

2.4. Statistical methods

Data analysis was performed using the SPSS27.0 software. Measurement data were presented as mean ± standard deviation (SD). We employed a group *t*-test for comparisons between groups and a paired *t*-test for within-group comparisons. Count data were reported as percentages (%), with relationships assessed using Pearson's correlation test. A P value of < 0.05 indicates statistically significant differences.

3. Results

3.1. Perioperative index

As shown in **Table 2**, the DAA group had a longer operation time, less blood loss, and a shorter incision length compared to the PLA group, with these differences being statistically significant ($P < 0.05$). The study found a strong correlation of 0.675 between BMI and operation duration in the PLA and DAA groups, which was highly statistically significant ($P < 0.001$).

Table 2. Perioperative index

	PLA (*n* = 48)	DAA (*n* = 53)	*P*
Operation time (min)	109.35 ± 12.026	123.47 ± 11.998	< 0.001
Amount of bleeding (ml)	279.17 ± 41.557	245.66 ± 39.735	< 0.001
Incision length (cm)	11.33 ± 1.917	9.79 ± 2.222	< 0.001

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach

3.2. Postoperative radiographic index

In comparison to the PLA group, we found a smaller yet statistically significant difference in the height of the rotation center and the center edge angle ($P < 0.05$), as illustrated in **Table 3**. The correlation between the height difference of the rotation center and the center edge angle was 0.863 ($P < 0.001$), indicating statistical significance. Additionally, our results indicated that the height difference in the center of rotation was not significantly related to gender ($P = 0.711$).

Table 3. Postoperative radiographic index

	PLA (*n* = 48)	DAA (*n* = 53)	*P*
The difference in RCH (mm)	6.718 ± 2.342	5.090 ± 1.922	< 0.001
The difference in CEA (°)	3.922 ± 1.390	2.941 ± 1.181	< 0.001

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach; RCH: Rotation center height; CEA: Central edge angle

3.3. Postoperative complications

After surgery, all patients experienced stage I healing of their incisions without complications, including infection, dislocation, or periprosthetic fracture. In the PLA group, four patients had a height difference of rotation centers greater than 10 mm, resulting in a complication rate of 8.33% (4/48). In contrast, the DAA group reported numbness in the lateral femoral skin innervation zone, with a complication rate of 5.66% (3/53). There was no significant difference between the two groups ($c^2 = 0.018$, $P = 0.892$).

4. Discussion

Our results indicated that patients in the DAA group had longer operation times but experienced less blood loss and shorter incisions compared to the PLA group. This agrees with the analysis by Sun *et al.* [26]. DAA procedures have a narrower operating space compared to other surgical approaches. In patients with acetabular issues, each additional unit of BMI increases surgery time by 0.9 minutes [27]. Additionally, our data revealed a positive linear correlation between BMI and surgery duration. Studies show that robotic-assisted technology can provide more precise cup positioning and better leg length recovery for obese patients [28]. In obese patients, special attention is given to correct reaming and subsequent positioning to avoid excessive lateral positioning [29].

Anatomical studies have identified morphological differences between male and female hip joints, which make women more prone to developing LLD postoperatively compared to men [30]. However, our results showed no significant correlation with gender. This may require categorizing the indicators of LLD before conducting correlation comparisons. It is noteworthy that the selection of the neck shows no gender differences and has no significant correlation with intraoperative ROM or postoperative dislocation [31]. LLD is influenced not only by bony relationships but also by varying degrees of tissue tension. The two-stage treatment involving skeletal traction for limb lengthening after extensive soft tissue release has shown good efficacy in addressing limb length discrepancies resulting from developmental dysplasia of the hip or sequelae of infectious hip disease [32]. Furthermore, the anterior-based muscle-sparing total hip arthroplasty (ABMS-THA), developed from the DAA approach, has been shown to yield better surgical outcomes [33].

Three-dimensional image analysis techniques (3D-IAT) can more accurately predict the position after surgery. These techniques significantly enhance the accuracy of component placement in joint replacement. This offers more options for patients needing THA.

Our data indicated that DAA is likely more effective than the conventional surgical approach in reducing LLD. In contrast to PLA, patients adopt the supine position when choosing the DAA approach during surgery, the pelvis stays in place, improving the accuracy of imaging feedback [34]. Although the positioning of the acetabular component in the recumbent position may differ from the postoperative standing position, 3D-IAT can more accurately predict the position of the acetabular component in the postoperative standing position [35,36]. Additionally, new non-invasive measurement techniques [37], such as robot-assisted (RA) and computer navigation (CN), assist in positioning acetabular components. These new techniques are superior to artificial THA (manual THA, mTHA) [38,39]. This will provide more options for patients requiring THA.

In 2024, researchers discovered a linear relationship between bilateral femoral offset (FO), bilateral rotational center height (RCH), and postoperative limb length discrepancy (LLD). This relationship can be expressed by the regression equation: $LLD = 0.038x - 0.099y + 0.257$, where x represents the difference in postoperative FO and y represents the difference in postoperative bilateral RCH, measured in centimeters. Additionally, reconstructing FO makes it easier to achieve equal lengths in the lower limbs [40]. The primary weakness of our study is its retrospective design, which did not include full-length photographs of patients' lower limbs, thus we were unable to predict and verify the value of LLD in postoperative patients using this formula. Additionally, the inclusion criteria were limited to four common THA indications: femoral neck fracture, hip osteoarthritis, femoral head osteonecrosis, and DDH. Research is lacking on whether DAA surgery is equally effective for other indications. Moreover, excluding patients over 80 years may introduce selection bias, artificially reducing the number of recorded postoperative complications. Furthermore, all patients in the study underwent hip replacement by the same joint surgeon, which included his learning curve [41]. Therefore, phased comparisons may be necessary to analyze the data results more effectively [42].

In future work, we will enhance the postoperative evaluation index to include various levels of orthopedic surgeons, and we will also verify the effects of other surgical approaches on patient outcomes through further prospective randomized controlled trials.

5. Conclusion

In short, DAA may effectively control LLD after THA, resulting in less blood loss and shorter incisions, though it may require longer operative time.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

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References

[1] Varacallo M, Luo TD, Johanson NA, 2024, Total Hip Arthroplasty Techniques, StatPearls Publishing, Treasure Island (FL).

[2] Rasheed A, Shaukat MK, Alam F, 2020, Mean Limb Length Discrepancy After Total Hip Arthroplasty. J Ayub Med Coll Abbottabad, 32(Suppl 1): S651–S654.

[3] Li W, Wu X, 2013, Lower Limb Inequality After Total Hip Replacement Surgery. International Journal of Orthopaedics, (34): 4.

[4] Fujita M, Hayashi S, Kamenaga T, et al., 2022, Ligament Preserving Total Hip Arthroplasty Prevents Different Leg Length and Femoral Offset. Acta Ortop Bras, 30(spe1): e242758.

[5] Mavcic B, Antolic V, 2021, Cementless Femoral Stem Fixation and Leg-Length Discrepancy After Total Hip Arthroplasty in Different Proximal Femoral Morphological Types. Int Orthop, 45(4): 891–896.

[6] Sun X, Qiu J, Jiang S, et al., 2023, Preoperative Leg Length Discrepancy >2 cm in the Supine Decubitus Position May Induce Compensatory Pelvic Obliquity in Patients during Total Hip Arthroplasty. Orthop Surg, 15(5): 1366–1374.

[7] Waibel FWA, Berndt K, Jentzsch T, et al., 2021, Symptomatic Leg Length Discrepancy After Total Hip Arthroplasty is Associated with New Onset of Lower Back Pain. Orthop Traumatol Surg Res, 107(1): 102761.

[8] Iwakiri K, Ohta Y, Fujii T, et al., 2021, Changes in Patient-Perceived Leg Length Discrepancy Following Total Hip Arthroplasty. Eur J Orthop Surg Traumatol, 31(7): 1355–1361.

[9] Chen G, Nie Y, Xie J, et al., 2018, Gait Analysis of Leg Length Discrepancy-Differentiated Hip Replacement Patients with Developmental Dysplasia: A Midterm Follow-Up. J Arthroplasty, 33(5): 1437–1441.

[10] Im CJ, Lee CY, Beom JY, et al., 2023, Stricter Correction of Leg Length Discrepancy is Required During Total Hip Arthroplasty in Patients with Ankylosing Spondylitis. BMC Musculoskelet Disord, 24(1): 781.

[11] Fujita K, Kabata T, Kajino Y, et al., 2020, Optimizing Leg Length Correction in Total Hip Arthroplasty. Int Orthop, 44(3): 437–443.

[12] Kawakami T, Imagama T, Matsuki Y, et al., 2023, Forgotten Joint Score is Worse When the Affected Leg Perceived Longer than Shorter After Total Hip Arthroplasty. BMC Musculoskelet Disord, 24(1): 440.

[13] Shi XT, Li CF, Han Y, et al., 2019, Total Hip Arthroplasty for Crowe Type IV Hip Dysplasia: Surgical Techniques and Postoperative Complications. Orthop Surg, 11(6): 966–973.

[14] Bose VC, Pichai S, Ashok Kumar PS, et al., 2021, Does Balancing a Total Hip Arthroplasty Require a New Paradigm? Functional 3-Dimensional Balancing in Total Hip Arthroplasty. Indian J Orthop, 55(5): 1240–1249.

[15] Ho KW, Whitwell GS, Young SK, 2012, Reducing the Rate of Early Primary Hip Dislocation by Combining a Change in Surgical Technique and an Increase in Femoral Head Diameter to 36 mm. Arch Orthop Trauma Surg, 132(7): 1031–1036.

[16] Peng L, Zeng Y, Wu Y, et al., 2022, Radiologic Restoration Inaccuracy Increases Postoperative Dislocation in Primary Total Hip Arthroplasty: A Retrospective study with Propensity Score Matching. Arch Orthop Trauma Surg, 142(12): 3995–4005.

[17] Li Z, Chu K, Yang M, et al., 2024, Does the Limb Lengthening Reduce the Incidence of Hip Dislocation in Patients with Neurological Disorders and Insufficient Muscle Tension Who Undergoing Hip Arthroplasty? Front Surg, (11): 1259039.

[18] Latijnhouwers D, Laas N, Verdegaal SHM, et al., 2022, Activities and Participation After Primary Total Hip Arthroplasty; Posterolateral Versus Direct Anterior Approach in 860 Patients. Acta Orthop, (93): 613–622.

[19] Wang Z, Bao HW, Hou JZ, et al., 2022, The Direct Anterior Approach versus the Posterolateral Approach on the Outcome of Total Hip Arthroplasty: A Retrospective Clinical Study. Orthop Surg, 14(10): 2563–2570.

[20] Rudin D, Manestar M, Ullrich O, et al., 2016, The Anatomical Course of the Lateral Femoral Cutaneous Nerve with

Special Attention to the Anterior Approach to the Hip Joint. J Bone Joint Surg Am, 98(7): 561–567.

[21] Luger M, Hipmair G, Schopper C, et al., 2021, Low Rate of Early Periprosthetic Fractures in Cementless Short-Stem Total Hip Arthroplasty Using a Minimally Invasive Anterolateral Approach. J Orthop Traumatol, 22(1): 19.

[22] Rivera F, Comba LC, Bardelli A, 2022, Direct Anterior Approach Hip Arthroplasty: How to Reduce Complications—A 10-Year Single Center Experience and Literature Review. World J Orthop, 13(4): 388–399.

[23] Xiong A, Li G, Liu S, et al., 2023, Anterolateral Approach May be Superior to Posterolateral Approach in Controlling Postoperative Lower Limb Discrepancy in Primary Total Hip Arthroplasty: A Single-Center, Retrospective Cohort Study. Jt Dis Relat Surg, 34(1): 32–41.

[24] Kishimoto Y, Suda H, Kishi T, et al., 2020, A Low-Volume Surgeon is an Independent Risk Factor for Leg Length Discrepancy After Primary Total Hip Arthroplasty: A Case-Control Study. Int Orthop, 44(3): 445–451.

[25] Free MD, Barnes I, Hutchinson M, et al., 2023, Preoperative Radiographs to Predict Component Malposition in Direct Anterior Approach Total Hip Arthroplasty. Hip Int, 33(2): 207–213.

[26] Sun X, Zhao X, Zhou L, et al., 2021, Direct Anterior Approach Versus Posterolateral Approach in Total Hip Arthroplasty: A Meta-Analysis of Results on Early Post-Operative Period. J Orthop Surg Res, 16(1): 69.

[27] Heinz T, Vasilev H, Anderson PM, et al., 2023, The Direct Anterior Approach (DAA) as a Standard Approach for Total Hip Arthroplasty (THA) in Coxa Profunda and Protrusio Acetabuli? A Radiographic Analysis of 188 Cases. J Clin Med, (12).

[28] Zhang S, Liu Y, Yang M, et al., 2022, Robotic-Assisted Versus Manual Total Hip Arthroplasty in Obese Patients: A Retrospective Case-Control Study. J Orthop Surg Res, 17(1): 368.

[29] Weibenberger M, Heinz T, Rak D, et al., 2024, Does Body Mass Index (BMI) Affect the Reconstruction of Biomechanical Parameters in Patients Undergoing Total Hip Replacement (THR) through the Direct Anterior Approach (DAA)? J Clin Med, 13(2).

[30] Huang Z, Zhang Z, Lu X, et al., 2023, The Influence of Prosthetic Positioning and Proximal Femoral Morphology on Leg Length Discrepancy and Early Clinical Outcomes of Cementless Total Hip Arthroplasty. J Orthop Surg Res, 18(1): 408.

[31] Shigemura T, Kamikawa K, Yamamoto Y, et al., 2024, Sex-Based Differences in Neck Selectivity in Total Hip Arthroplasty using a Modular Femoral Neck System. Int J Artif Organs, 47(4): 290–298.

[32] Lee SJ, Yoon KS, 2021, Two-Stage Total Hip Arthroplasty Following Skeletal Traction After Extensive Soft Tissue Release for Severe Limb-Length Discrepancy. Hip Int, 31(2): 223–230.

[33] Civinini R, Cozzi Lepri A, Carulli C, et al., 2019, The Anterior-Based Muscle-Sparing Approach to the Hip: The “Other” Anterior Approach to the Hip. Int Orthop, 43(1): 47–53.

[34] Dunn H, Rohlfing G, Kollmorgen R, 2020, A Comparison of Leg Length Discrepancy between Direct Anterior and Anterolateral Approaches in Total Hip Arthroplasty. Arthroplasty, 2(1): 30.

[35] Coxe FR, Jordan LA, Wong ZP, et al., 2024, Functional Acetabular Component Positioning During Direct Anterior Approach Hip Arthroplasty Using a Novel Three-Dimensional Virtual Mesh Imaging System with Fluoroscopy. J Arthroplasty, 39(9s1): S88–S96.

[36] Sariali E, Catonne Y, Pascal-Moussellard H, 2017, Three-Dimensional Planning-Guided Total Hip Arthroplasty Through a Minimally Invasive Direct Anterior Approach. Clinical Outcomes at Five Years’ Follow-Up. Int Orthop, 41(4): 699–705.

[37] Kezer M, Kizilay YO, 2024, A Novel Approach for Correcting Limb Length Discrepancy in Total Hip Arthroplasty. Cureus, 16(3): e56628.

[38] Tu Y, Wan D, Wang Q, 2022, Meta-Analysis of Leg Length Discrepancy After Robot-Assisted and Traditional Total Hip Arthroplasty. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi, 36(5): 561–566.

[39] Hecht CJ, 2nd, Nedder VJ, Porto JR, et al., 2024, Are Robotic-Assisted and Computer-Navigated Total Hip Arthroplasty Associated with Superior Outcomes in Patients Who Have Hip Dysplasia? J Orthop, (53): 125–132.

[40] Li MY, Cao W, Sha PX, et al., 2024, Correlation Between Femoral Offset, Rotation Center and Leg Length Discrepancy After Total Hip Arthroplasty Based on Digital Analysis. Zhongguo Gu Shang, 37(4): 381–386.

[41] Kim CY, Chung YY, Shim SW, et al., 2020, Early Experience of Direct Anterior Approach Total Hip Arthroplasty: Analysis of the First 53 Cases. Hip Pelvis, 32(2): 78–84.

[42] Metzger CM, Farooq H, Hur JO, et al., 2022, Transitioning from the Posterior Approach to the Direct Anterior Approach for Total Hip Arthroplasty. Hip Pelvis, 34(4): 203–210.