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ORIGINAL ARTICLE

Accuracy analysis of artificial intelligence-assisted three-dimensional preoperative planning in total hip replacement

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Total hip arthroplasty (THA) is the most effective method for end-stage hip disease and is one of the most successful procedures in orthopedic surgery.[1] Appropriate prosthesis selection, accurate prosthesis installation, and recovery of lower-limb length are the key factors affecting the postoperative course. Poor prosthesis size and positioning aggravate joint load and wear and increase the risk of prosthesis impingement and joint dislocation.[2,3] Postoperative unequal lower limbs can cause adverse events, such as lameness, knee pain and pelvic tilt, which is the primary cause of patient dissatisfaction following THA.[4] A large number of clinical reports have demonstrated that accurate preoperative planning is useful for determining the prosthesis model, restoring the rotation center position, optimizing prosthesis positioning, correcting the unequal length of both lower limbs, and reducing surgical complications.[5-7]

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ABSTRACT

Objectives: This study aims to assess the outcome of total hip arthroplasty (THA) using artificial intelligence (AI)-assisted three-dimensional (3D) preoperative planning technology in terms of predicting prosthesis size, acetabular cup positioning, and lower-limb length restoration.

Patients and methods: Between January 2020 and July 2022, a total of 161 patients (101 males, 60 females; mean age: 57.6±10.5 years; range, 31 to 80 years) who underwent primary unilateral THA were retrospectively analyzed. The patients were divided into two groups as those who were treated with AI-assisted 3D preoperative planning technology (the observation group, n=95) and patients who were treated with traditional two-dimensional (2D) X-ray template planning technology (the control group, n=66).

Results: The accuracy of the planning was based on the consistency of the preoperative planning and intraoperative models. The difference between the observation group and the control group was statistically significant in terms of the accuracy of the preoperative planning of acetabular prostheses (54% *vs*. 38%, p=0.048) and femoral prostheses (64% *vs*. 44%, p=0.011), with both values significantly higher in the observation group. The mean inclination angle, anteversion angle, and limb length discrepancy (LLD) in the observation group were 36.85°±4.82°, 12.10°±5.33°, and 2.18±2.70 mm, respectively, while those in the control group were 35.06°±6.07°, 10.95°±5.09°, and 4.42±3.85 mm, respectively. There was a statistically significant difference between the two groups in terms of inclination angle and LLD (p<0.05 for both), but there was no significant difference in terms of anteversion angle (p>0.05). In the observation group, 86.3% (82/95) of acetabular cups were implanted within the Lewinnek safe zone (72.7% [48/66] in the control group), while 83.2% (79/95) were within the Callanan safe zone (69.7% [46/66] in the control group), with both values higher in the observation group (p<0.05).

Conclusion: Overall, AI-assisted 3D preoperative planning is superior to traditional 2D X-ray template planning for predicting prosthesis size, and it also has the advantage in terms of acetabular cup positioning and lower-limb length restoration.

Keywords: Acetabular cup positioning, artificial intelligence, lower-limb length discrepancy, prosthesis size, total hip arthroplasty, 3D preoperative planning.

Currently, most domestic hospitals use traditional X-ray film template measurements for THA preoperative design, while some hospitals use the two-dimensional (2D) digital template measurement method (e.g., OrthoView, LINK Preop PLAN, and other planning software).[8] However, 2D planning based on X-ray films is affected by the shooting angle, the magnification rate and the complexity of the lesion anatomy, leading to many errors and measurement limitations. In short, the surgeon must adjust the prosthesis model and its position according to his/her own experience, thereby extending the operation time and increasing the risk of bleeding and infection.[9,10] Three-dimensional (3D) preoperative planning based on computed tomography (CT) data (e.g., Mimics, MAKO, and ZedHip) is thought to improve the accuracy of prosthesis placement and reduce surgical complications;[11,12] however, this method is limited in terms of the complicated planning steps and the time involved, restricting its clinical application.

Artificial intelligence (AI)-assisted preoperative 3D planning is an emerging digital orthopedic technology in the field of joint replacement. A 3D model is automatically generated from imported CT data. Based on big data analytics and deep self-learning, the method automatically identifies the most appropriate prosthesis and places it in the best position, providing more information for the surgeon. Some studies have reported that the use of AIHIP software (Beijing Changmugu Co., Ltd., Beijing, China) significantly reduces the time and manpower required for detailed preoperative planning, and is more accurate than traditional planning methods.[8,13]

However, AI-assisted preoperative 3D planning has not been widely applied in China, and there are only a few relevant reports in the literature. In the present study, we, therefore, aimed to evaluate case data on AI planning-assisted THA and traditional planning-assisted THA and to analyze prosthesis-type agreement rate between the preoperative planning and the actual intraoperative application, the position of the acetabular prosthesis and the correction of the unequal length of both lower limbs, and the accuracy of AI-assisted preoperative 3D planning for THA.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Ningxia Medical University General Hospital, Department of Orthopedics and Traumatology between January 2020 and July 2022. Perioperative data of patients undergoing unilateral and primary THA were collected. Patients undergoing THA assisted by a preoperative AI hip (AIHIP) 3D planning software system were allocated to an observation group (the AI planning group, n=95), while those who underwent THA with the traditional X-ray film template method were allocated to a control group (the traditional planning group, n=66). Inclusion criteria were as follows: *(i)* patients with unilateral hip pain seriously affecting their daily life; *(ii)* use of a standard posterolateral approach of the hip joint; *(iii)* normal contralateral hip joint or having THA; *(iv)* the Dorr typing of the proximal femur on the affected side (type A or B and V) and the biotype artificial hip joint as the prosthesis manufactured by Johnson & Johnson (PINNACLE® cup, SUMMIT™ handle). Exclusion criteria were as follows: *(i)* pre- and postoperative imaging examinations that did not meet the eligibility criteria (i.e., non-standard hip joint anteroposterior projection, and precise measurement of the acetabular angle and lower-limb length could not be performed); *(ii)* severe osteoporosis, tumor, and/or metabolic diseases around the hip joint on the affected side; *(iii)* patients with a history of spinal deformities or lumbar internal fixation surgery; *(iv)* deformities in the lower extremities other than the hip joint on the affected side; *(v)* neuromuscular insufficiency (with hip abduction weakness, polio); and *(vi)* patients with severe disease who could not tolerate surgery. Finally, a total of 161 patients (101 males, 60 females; mean age: 57.6±10.5 years; range, 31 to 80 years) were included in the study.

Preoperative planning

The AI planning group utilized AI-assisted 3D planning to complete preoperative design. All patients underwent bilateral hip joint CT scans, and the DICOM data was imported into AIHIP software to generate 3D images. Based on big data and deep learning, the appropriate type of prosthesis was automatically matched and placed in the optimal position (target angle of external rotation 40° and anterior tilt 20°). Surgeons were allowed to manually adjust the size and position of the prosthesis in various planes and record the final prosthesis model, position, angle, level of femoral neck osteotomy, predicted recovery of lower-limb length and offset distance, after they were satisfied with the placement (Figures 1-3). The traditional planning group utilized traditional X-ray film templates to complete preoperative design. Surgeons assessed the position, size, level of femoral neck osteotomy, and predicted recovery of lower-limb length and offset distance of the prosthesis on X-ray. Once they were satisfied with the placement, they recorded the planned model.

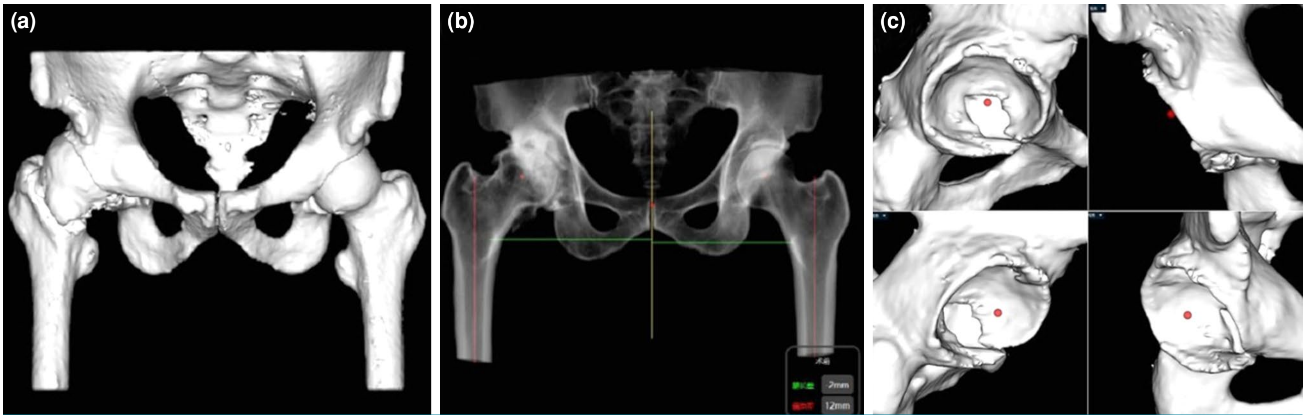

FIGURE 1. Preoperative 3D reconstruction, and parameter measurement. **(a)** Shows the automatic generation of the 3D pelvic reconstruction model by the AIHIP software; **(b)** shows the preoperative parameters, the red line represents the axis of the femoral bone marrow cavity, the green line represents the horizontal axis of the tip of the femoral lesser trochanter, preoperative lower-limb length discrepancy and offset are shown; **(c)** shows a 3D view of the acetabulum.
AIHIP: Artificial intelligence hip.

Surgical procedure

All prostheses were biotype artificial hip prostheses with a ceramic femoral head and a high cross-linked polyethylene lining. All procedures were performed by a single surgeon. The THA surgery was carried out using general anesthesia and a standard posterolateral approach. The femoral head was amputated according to the planned location of the femoral neck, and an acetabular lateral contusion was initially performed. The location, depth, abduction angle and anteversion angle of the acetabular contusion were determined based on specific anatomical landmarks (e.g., the acetabular transverse ligament), the surgeon's experience, and preoperative planning before the acetabular true mortar applied to the petechial hemorrhage of cancellous bone was polished, and the acetabular prosthesis and the corresponding lining were inserted. After grinding the femur and implanting it with the femoral stem, the stability and length of the lower limb were assessed according to the tension degree of the joint capsule and the position of the knee joint on both sides, with the model of the femoral stem and femoral head selected accordingly. None of the patients underwent intraoperative fluoroscopy.

The preoperative planning of the measurement results provided a useful reference. The most suitable prosthesis was selected according to the

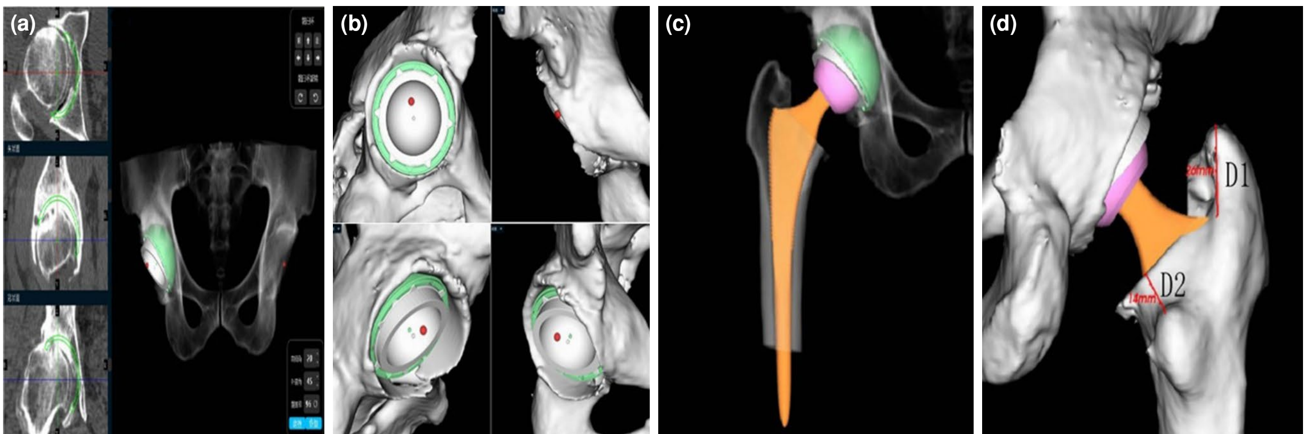

FIGURE 2. The design of prosthesis position. **(a)** Shows the position and angle of the designed acetabular cup; **(b)** shows a 3D view of the acetabular cup; **(c)** shows a 3D view of the femoral components; **(d)** shows the location of femoral neck resection, D1 is the distance from the tip of the greater trochanter to the shoulder of the femoral component, D2 is the distance from the superior edge of the lesser trochanter to the osteotomy plane.

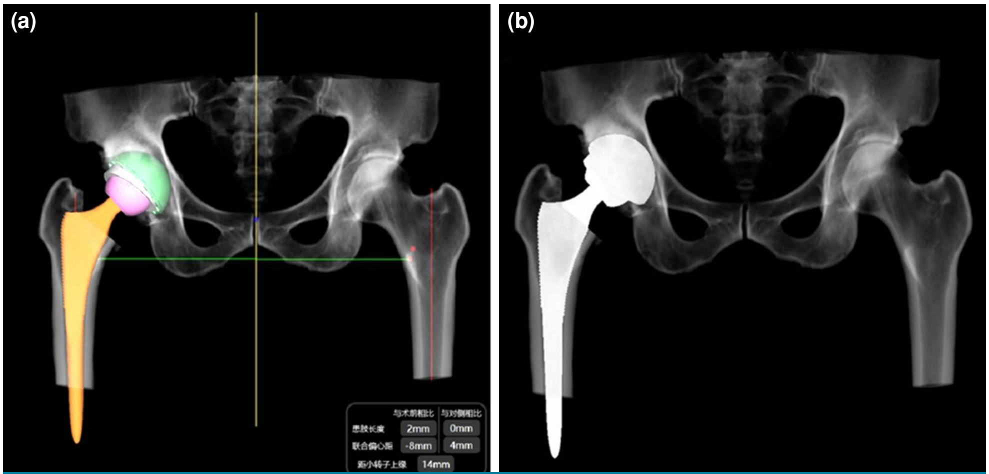

FIGURE 3. Postoperative simulation. **(a)** Is the postoperative 3D simulation, the red line represents the axis of the femoral bone marrow cavity, the green line represents the horizontal axis of the tip of the femoral lesser trochanter, simulated postoperative lower-limb length discrepancy and offset are shown; **(b)** is the postoperative X-ray simulation.

actual intraoperative conditions, and all the surgical procedures went smoothly. Two cases in the AI planning group had a proximal femoral fracture during the implantation of the femoral stem prosthesis, and wire ring ligation and fixation treatments were given. Four cases in the traditional planning group had a proximal femoral fracture during the implantation of the femoral stem prosthesis and were administered wire ring ligation and fixation. No other intraoperative complications occurred.

Postoperative management

Symptomatic treatments, such as anticoagulation and analgesia, were administered routinely following surgery, and the patients were guided in exercising the affected limb. The day after surgery, all patients were asked to partially keep their weight off the ground using crutches.

Outcome measures

In this study, we used a single-blinded approach, and all pre- and postoperative index measurements were performed by a trained research group physician who was not involved in the surgical treatment of the patients. The allocation of the patient groups was unknown, when the data measurements and statistical analysis were performed.

The perioperative complications and operation time (skin cutting to suture end time) were recorded for all patients. The acetabular cup prosthesis and femoral stem were recorded in terms of preoperative planning and practical application in all patients. If the preoperative planning model was exactly consistent with the actual application model, the preoperative planning was regarded as accurate. A result of 'completely in line' or a difference of 1 indicated that the model was excellent.

The precision of acetabular cup prosthesis implantation was assessed using X-ray filming of the hip joint anteroposterior projection on the day after surgery. The abduction angle and the anteversion angle of the postoperative acetabular cup prosthesis were measured and recorded, and the proportion of the acetabular cup prosthesis located in the Lewinnek safe zone was calculated. The abduction angle of the acetabular cup was defined as the lateral angle between the long axis of the acetabular cup and the line connecting the teardrops on both sides (Figure 4a). The anteversion angle of the acetabular cup was the forward inclination: = arcsin (short axis/long axis) (Figure 4b). The abduction angle and the anteversion angle of each patient were compared with those of the Lewinnek safe zone (abduction angle 30°-50°, anteversion angle 5°-25°) and the Callanan safe zone (abduction angle 30°-45°, anteversion angle 5°-25°), and the proportion of postoperative acetabular prosthesis located in the Lewinnek safe zone and the Callanan safe zone in each group was calculated. The formula of coefficient of variation = (standard deviation/mean) ×100.

The limb length discrepancy (LLD) was measured using the X-ray of the hip joint anteroposterior projection on the day after surgery. The difference in vertical distance from the bilateral femoral lesser

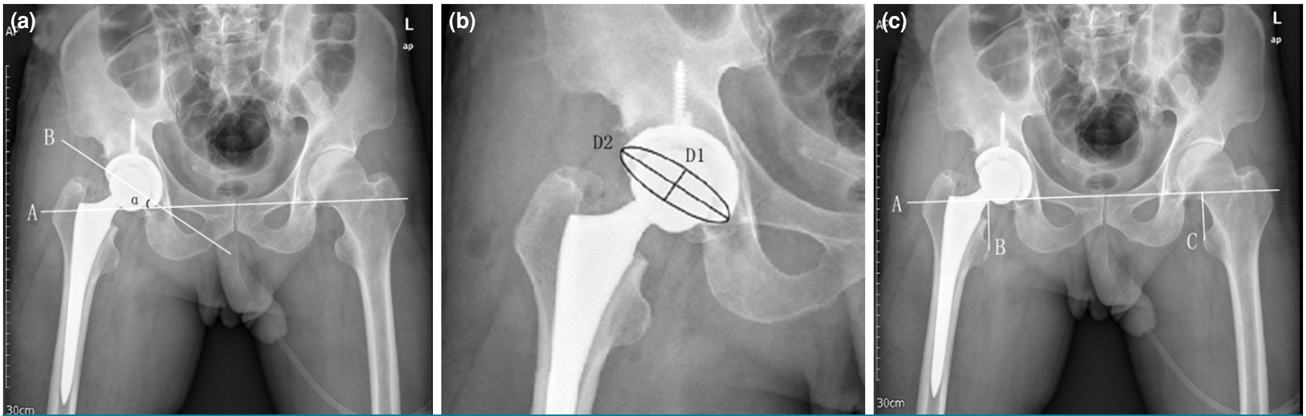

FIGURE 4. Postoperative measurement of acetabular angle and both lower-limb length. **(a)** Shows the measurement of the acetabular abduction angle. A is the line connecting the tear drops on both sides. B is the long-axis connection of the acetabular cup. The lateral angle (α) between A and B is the abduction angle. **(b)** shows the acetabular anteversion angle measurement. D1 is the short axis of acetabular cup oval shadow. D2 is the long axis of the acetabular cup oval shadow. Anteversion angle = arcsin (D1/D2). **(c)** shows the LLD measurements. A is the line connecting lower edge of the tear drops on both sides. B and C are the vertical distance from the tip of the femoral lesser trochanter to A of the operative and contralateral side, respectively. The difference between B and C is the difference in lower-limb length.
LLD: Limb length discrepancy.

trochanter tip to the line connecting both teardrops was measured, and the difference between the operative side and the contralateral side gave the LLD. Positive values indicated a lengthening on the operative side, and negative values indicated a shortening on the operative side. The LLD absolute values were recorded (Figure 4c).

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in mean ± standard deviation ($\bar{x}$±SD) or median (min-max), while categorical data were expressed in number and frequency. The independent-sample t-test or paired t-test was used to compare continuous variables. Categorical data were analyzed using the chi-square test (χ^2). A two-sided *p* value of <0.05 was considered statistically significant.

RESULTS

There was no significant difference in the age, sex, body mass index (BMI), preoperative diagnosis, Dorr typing of the proximal femur and preoperative LLD between the groups (p>0.05) (Table I).

The surgeries in the two groups went smoothly, no anesthesia or cardiovascular/cerebrovascular accidents occurred during the perioperative period, and the incisions healed well. However, the operation time in the AI planning group was slightly shorter than in the traditional planning group, although the difference was not statistically significant (p>0.05) (Table II).

In the AI planning group, the complete accuracy of the preoperative planning model of acetabular prosthesis and femoral prosthesis that was consistent with the actual intraoperative model was 54% (51/95) and 64% (61/95), respectively, with an excellent accuracy accounting for 92% (87/95) and 98% (93/95), respectively. In the traditional planning group, the complete accuracy of the preoperative planning model of the acetabular and femoral prostheses that was consistent with the actual preoperative planning model was 38% (25/66) and 44% (29/66) respectively, with the excellent rate at 88% (58/66) and 85% (56/66), respectively. There were statistically significant differences in the complete accuracy of the acetabular and femoral prostheses and the excellent rate of the femoral prostheses between the two planning methods (p<0.05) (Table III).

In all patients, the mean abduction angle of the postoperative acetabular prosthesis was 36.12°±5.42°, while the mean anteversion angle was 11.63°±5.25°. The mean abduction angle and the anteversion angle of the AI planning group were 36.85°±4.82° and 12.10°±5.33°, respectively, while those of the traditional planning group were 35.06°±6.07° and 10.95°±5.09°, respectively. The difference in the abduction angle between the two groups was significant (p<0.05), while the difference in the anteversion angle was

TABLE I
Baseline data of the patients

Item	AI planning group (n=95)		Traditional planning group (n=66)		χ^2 value/t value	*p* value
	n	$\bar{x}$±SD	n	$\bar{x}$±SD		
Age (year)		57.5±10.5		57.8±10.6	-0.183	0.855
Sex					0.740	0.390
Male	57		44			
Female	38		22			
Body mass index (kg/m²)		25.3±3.0		24.7±3.8	1.088	0.278
Preoperative diagnosis					1.880	0.866
Necrosis of the femoral head	40		28			
Developmental dysplasia of the hip	36		24			
Osteoarthritis	13		10			
Rheumatoid arthritis	4		1			
Femoral neck fracture	1		2			
Ankylosing spondylitis	1		1			
Dorr typing of the proximal femur					3.506	0.061
Type A	10		14			
Type B	85		52			
Preoperative LLD		9.45±7.78		11.06±9.26	-1.190	0.236

AI: Artificial intelligence; $\bar{x}$±SD: Mean ± standard deviation; LLD: Limb length discrepancy.

not (p>0.05). The abduction angle, anteversion angle range and coefficient of variation were smaller in the AI planning group than in the traditional planning group, indicating that the dispersion degree of the abduction and anteversion angles was lower in the AI planning group and that the individual differences were smaller (Table IV).

Using the Lewinnek safe zone (abduction angle 30°-50°, anteversion angle 5°-25°) as the standard, the proportion of acetabular prostheses located in the safety zone in the two groups was 86.3% (82/95) and 72.7% (48/66), respectively. With the stricter Callanan safe zone used as the standard (abduction angle 30°-45°, anteversion angle 5°-25°),

TABLE II
Comparison of operation time between the two groups

	AI planning group	Traditional planning group	t value	*p* value
	$\bar{x}$±SD	$\bar{x}$±SD		
Operation time (min)	78.5±18.5	83.6±18.7	-1.686	0.094

AI: Artificial intelligence; $\bar{x}$±SD: Mean ± standard deviation.

TABLE III
Comparison of planning accuracy of acetabular and femoral prosthesis between the two groups

	AI planning group		Traditional planning group		χ^2 value	*p* value
	n	%	n	%		
Complete accuracy of acetabular cup	51	53.7	25	37.9	3.904	0.048
Complete accuracy of the femoral stem	61	64.2	29	43.9	6.492	0.011
Excellent rate of ace-tabular cup	87	91.6	58	87.9	0.596	0.440
Excellent rate of femoral stem	93	97.9	56	84.8	9.609	0.002

AI: Artificial intelligence.

TABLE IV
Comparison of abduction angle and anteversion angle of acetabular cup prosthesis between the two groups

	AI planning group				Traditional planning group					
	n	%	x̄±SD	Range/ Coefficient of variation	n	%	x̄±SD	Range/ Coefficient of variation	χ^2 value/ t value	*p* value
Postoperative abduction angle			36.85°±4.82°	21.79/13.1			35.06°±6.07°	33.64/17.3	2.079	0.039
Postoperative anteversion angle			12.10°±5.33°	21.80/44.0			10.95°±5.09°	24.00/46.5	1.374	0.172
Lewinnek safety area	82	86.3			48	72.7			4.625	0.032
Callanan safety area	79	83.2			46	69.7			4.065	0.044

AI: Artificial intelligence; x̄±SD: Mean ± standard deviation.

the proportion of the two acetabular prostheses located in the safe zone of the two groups was 83.2% (79/95) and 69.7% (46/66), respectively. There were significant differences between the two groups ($p<0.05$) (Figure 5).

The mean absolute value of the preoperative LLD in the AI planning group and the traditional planning group was 9.45±7.78 and 11.06±9.26 mm, respectively, and the difference was not significant ($p>0.05$). Compared to preoperative values, the postoperative LLD was significantly corrected in the two groups, with statistically significant differences ($p<0.01$). The mean absolute value of postoperative LLD was 2.18±2.70 mm in the AI planning group and 4.42±3.85 mm in the traditional planning group, with a statistically significant difference ($p<0.01$). The correction of LLD was better in the AI planning group (Table V).

DISCUSSION

The prediction accuracy of artificial hip replacement preoperative planning has gradually improved, from widely used 2D digital templates to more recent 3D planning software; however, the operation process of most of the 3D planning software still remains relatively cumbersome and time-consuming. In the present study, we used a 3D AIHIP system for preoperative planning in patients with primary total hip replacement. Our study results revealed that, in the AI planning group, the complete accuracy

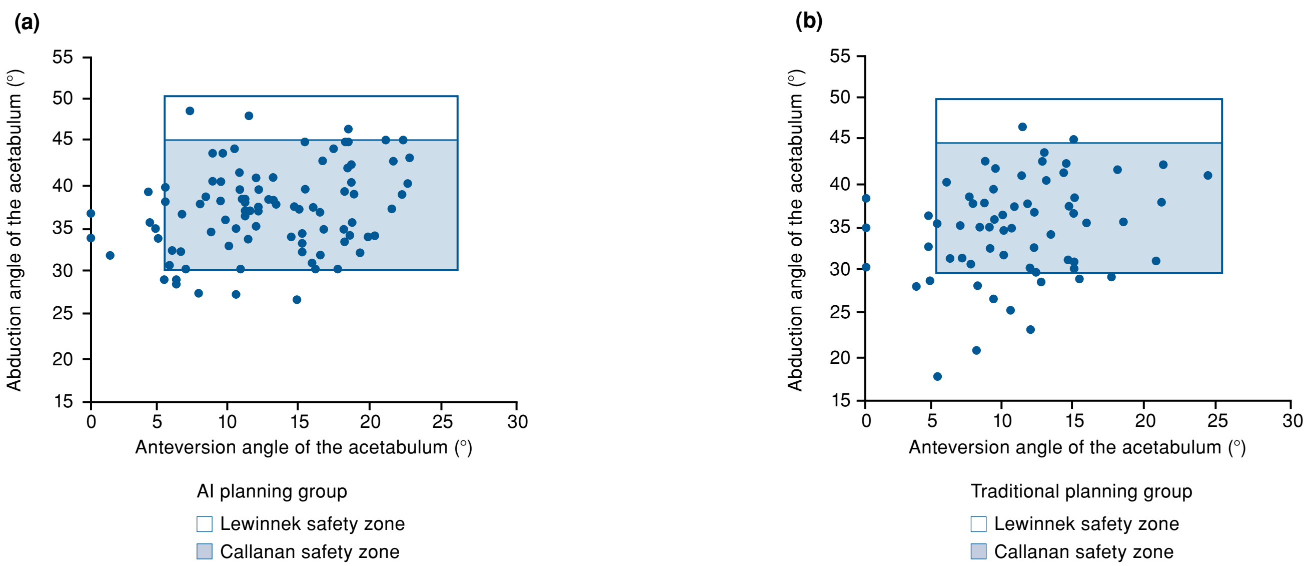

FIGURE 5. Scatter plot of postoperative acetabular prosthesis position. **(a)** Shows the situation of postoperative acetabulum located in the safety area of the AI planning group; **(b)** shows the situation of postoperative acetabulum located in the safety area of the traditional planning group.

TABLE V
Comparison of pre- and postoperative LLD between the two groups

	AI planning group	Traditional planning group		
	x̄±SD	x̄±SD	t value	*p* value
Preoperative LLD (mm)	9.45±7.78	11.06±9.26	-1.190	0.236
Postoperative LLD (mm)	2.18±2.70	4.42±3.85	-4.332	<0.001
t value	8.610	5.381		
p value	<0.001	<0.001		

LLD: Limb length discrepancy; AI: artificial intelligence; x̄±SD: Mean ± standard deviation.

of the acetabular cup prosthesis was 54% and that of the femoral stem prosthesis was 64%, indicating that the accuracy of AI preoperative 3D planning for predicting the prosthesis model was significantly higher than that of the traditional X-ray film template method.

Two-dimensional planning based on X-rays has the low accuracy and replication. Related studies have reported that the accuracy of 2D planning for the acetabular cup was 7.3 to 70%, with 36 to 79% for the femoral stem.[14-17] Danoff et al.[18] found that the proportion of acetabular prostheses biased from the Lewinnek safe zone was up to 37% in 1,289 cases of conventional THA, while Nossa et al.[19] reported that the proportion of LLD ≥10 mm was up to 20% following conventional THA.

With the advent of digital orthopedics, 3D preoperative planning based on CT data demonstrates excellent planning capabilities. Previous reports on 3D planning have demonstrated the high accuracy and replication of the method, with the accuracy of the acetabular cup ranging from 52 to 96% and that of the femoral stem ranging from 63 to 100%.[20,21] In addition, 3D imaging can intuitively present the spatial anatomy of the patient's lesion, which is useful for the preoperative planning of the prosthesis's parameters, thereby reducing the number of repeated intraoperative measurements and comparisons of the prosthesis and achieving the purpose of reducing the operation time, the amount of bleeding and complications.[22-24] However, for complex cases, particularly in those with many osteophytes around the hip joint, 3D preoperative planning requires film reading and processing of the CT images along with 3D reconstruction and manual identification of the best position for prosthesis placement; furthermore, the preoperative design process and operation time are long.[25-27]

The AIHIP software system is a preoperative planning operating system developed in China that combines AI with 3D planning. Based on the preoperative CT scan data of patients and intelligent separation, it quickly realizes the 3D reconstruction of an anatomical model and intelligently identifies the anatomical sites. Furthermore, based on big data analytics, the system carries out deep self-learning, absorbs the knowledge and concept of many domestic orthopedic physicians and experts and intelligently matches the optimal prosthesis model and optimal position according to the anatomical shape of the acetabulum and femur. The system is also simple to operate and use, reducing both staffing and the material resources used in the preoperative design process, and it is truly intelligent, refined and individualized.

In terms of predicting the prosthesis model, in the traditional planning group, the complete accuracy of the preoperative design of the acetabular cup and femoral stem and the intraoperative actual prosthesis model was 38% and 44%, respectively, which is similar to the results reported in previous studies,[28-30] while the complete accuracy of the AI planning group was 54% and 64%, respectively. If full compliance or the difference of one model was excellent, the excellent rate of the AI planning group was 92% and 98% respectively. There were statistically significant differences in the complete accuracy in terms of acetabular and femoral prostheses and the excellent rate of femoral prostheses between the two planning methods. Huo et al.[8] also confirmed that based on AI technology and big data, The AI HIP showed excellent reliability for component size in THA. This result suggests that AI preoperative 3D planning performs well for the highly accurate prediction of prosthesis models, and its planning accuracy within one model difference is better than that of the traditional planning method, particularly in terms of femoral prosthesis planning.

Despite the high accuracy of AI 3D planning, there were still differences that exceeded two models of acetabular cup planning in eight cases and of femoral stem planning in two cases. In eight cases with poor acetabular cup planning, the prosthesis model predicted via AI 3D planning was two sizes larger, and the eight patients were diagnosed with developmental dysplasia of the hip (DDH), which may have been related to lesion characteristics, surgical habits and AI planning characteristics. In DDH, the acetabulum is moved up, and the socket is shallow. The surgeon in our department usually placed the acetabular cup at the original true acetabular position. The prosthesis model with stable pressure matching of the anterior wall and posterior wall and adequate coverage of the acetabular cup was selected to match the standard as far as possible, and the use of smaller models during the operation was preferred. In two cases, the femoral stem planning prior to the operation was two sizes larger than the actual intraoperative application, largely because the opening of the marrow cavity of the femoral bone was valgus and the prosthesis was slightly varus and because the distal femoral stem underwent premature contact with the cortical bone during the operation, which affected further penetration.

The acetabular abduction and anteversion angles were larger in the AI planning group than in the traditional planning group, with the former closer to the angle of preoperative planning. In addition, the abduction and anteversion angle range and the coefficient of variation were smaller in the AI planning group than in the traditional planning group, indicating that the dispersion degree of the abduction and anteversion angles and the inter-individual differences were smaller in the former group. In terms of the proportion located in the safe zone, the proportion of acetabular prostheses located in the Lewinnek safe zone and the Callanan safe zone was 72.73% and 69.7%, respectively, in the traditional planning group, similar to the results of a previous study,[31] while the proportion of the two items in the AI planning group was 86.32% and 83.2%, respectively, which was significantly higher than in the traditional planning group. This result suggests that the AI 3D planning-assisted preoperative design method results in more accurate, safer, and more reproducible acetabular prosthesis placement.

In terms of lower-limb length recovery, previous studies have suggested that the main reason for LLD following total hip replacement is the improper positioning of the femoral stem.[32] The mean absolute value of postoperative LLD was lower in the AI planning group than in the traditional planning group, suggesting that the LLD correction was better in the former group; this may have been related to the accurate femoral neck osteotomy location and the distance from the great trochanter tip of the femur to the prosthesis shoulder in the preoperative design of AI 3D planning for intraoperative reference.

This study confirmed the superiority of AI 3D preoperative planning compared to conventional X-ray film template 2D planning. The AIHIP design system allows for precise positioning of the prosthesis using the geometric relationship between the hip joint and the prosthesis before surgery. Compared to previous preoperative design methods, the AIHIP system can achieve a more precise match between the prosthesis and the patient. However, the system has several shortcomings. First, due to the relevant conditions, the current AIHIP design system can only be used for the planning of fixed products, and the range of prosthetic options is relatively small. Second, due to the need for thin-layer CT scans, patients receive relatively more radiation, and the economic costs increase accordingly. Third, the system requires separate data that must be uploaded by the physician, which is both time-consuming and costly. Fourth, the AIHIP system requires clinicians to be proficient in the use of the software, meaning they must undertake specialised training, thus increasing pressure on clinicians' workloads.

Nonetheless, this study has several limitations. First, it is a retrospective study; the grouping based on preoperative planning was non-randomized, and the level of evidence was lower than that obtained from prospective studies. However, there was no significant difference in patients' baseline data (age, sex, BMI, preoperative diagnosis, Dorr typing of proximal femur and preoperative LLD). At the same time, strict inclusion and exclusion criteria were applied, while the quality of the imaging examination was standardized and improved, which reduced bias to some extent. Second, since the follow-up time was constrained by the available resources and the timeframe of the research project, statistics on intraoperative blood loss, postoperative functional score, postoperative mobility parameters and long-term complications were not considered. Third, while prosthesis placement location and postoperative LLD correction were better in the AI planning group, whether this advantage of prosthesis accuracy is reflected in the medium-and long-term follow-up results is yet to be ascertained. Fourth, while the AIHIP system can provide accurate preoperative planning, it still requires the intraoperative judgment and experience of doctors while applying preoperative planning in practice, particularly in complex cases. However, this study is a single-center, single-operator cohort study, and the surgeon had extensive experience in joint replacement surgery, which ensured that the baseline value of the control group was high, potentially impacting the index comparisons. Finally, the AIHIP operating system is an emerging technology, and with the incorporation of AI systems in the planning of surgical cases and the feedback of experts and scholars, the accuracy of preoperative design will continue to improve. Future prospective randomized studies with a large sample size are needed to draw more reliable conclusions on this subject.

In conclusion, the AI preoperative 3D planning method is significantly superior to the conventional X-ray film template 2D planning method for predicting prosthesis models, thereby improving the accuracy of acetabular prosthesis implantation.

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Patient Consent for Publication: A written informed consent was obtained from each patient.

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