

The role of AIHIP in Preoperative Planning of Total Hip Arthroplasty to Different Surgeons.

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Abstract

Background

Preoperative planning with computed tomography (CT)-based three-dimensional templating has been achieved more precise placement of hip components. This study investigated the value of the software for preoperative planning (artificial intelligence hip system, AIHIP) in primary total hip arthroplasty (THA) for surgeons with different experience levels.

Methods

We performed a retrospective study of 240 hips in 240 patients who underwent cementless primary THA. The patients were divided into four groups: A1) senior surgeon without AIHIP, A2) senior surgeon with AIHIP, B1) junior surgeon without AIHIP, and B2) junior surgeon with AIHIP. All preoperative planning evaluations were completed using the AIHIP software. We analysed the accuracy of stem size prediction and cup size prediction, the absolute value of postoperative discrepancy in leg length, discrepancy of neck-shaft angle and femoral offset between the healthy side and the affected side from the anteroposterior radiographic view of the hip, intraoperative and postoperative complications, operative times, the reduction in the haemoglobin (Hb) level during the first 24 hours and the number of intraoperative radiations.

Results

The sizes of 95% were accurately estimated to be within one stem size, and 97% of the cup size estimates were accurate to within one cup size in group A2. A total of 87% were accurately estimated to be within one stem size, and 85% were accurate to within one cup size in group B2. There was a significant difference in radiological indicators ($P < 0.050$), postoperative complications (overall $P = 0.035$), operation duration ($P < 0.001$), decrease in Hb per 24 hours ($P = 0.046$) and intraoperative radiation frequency ($P < 0.050$) among the patients in group B. There was also a significant difference in postoperative complications (overall $P = 0.01$) between groups A1 and B1.

Conclusion

Our results suggest that the AIHIP is a favourable tool for young surgeons, and the accuracy is good.

1. Background

Total hip arthroplasty (THA) has proven to be one of the most reliable procedures for the treatment of hip disease in terms of improving function and quality of life [1]. However, appropriate and meticulous preoperative planning is necessary. Accurate prediction of implant size during preoperative planning is an important factor for successful reconstruction to avoid intraoperative or postoperative complications [2]. Preoperative planning can also help the surgeon perform the procedure expediently as well as achieve reproducible, desired results [3]. In addition, accurate size prediction may facilitate inventory cost savings and reduce the risk of opening (and thus wasting) an implant of the wrong size.

In recent years, preoperative planning with computed tomography (CT)-based three-dimensional (3D) templating has been expanded. In preoperative planning, CT-based 3D templating showed excellent reliability for component size and alignment in THA. Deformity of the affected joint influenced the reliability of preoperative planning [4]. CT-based 3D templating software for THA showed excellent interobserver and intraobserver reliabilities and was found to have excellent reproducibility and precision [4] [5]. The advantages of standardized CT for preoperative planning include the avoidance of imprecise magnification factors and inaccurate acquisition position by conventional radiographs, availability of an additional axial plane and the replacement of projections by thin slices. Representative software programs include Materialize Mimics by the company Materialize NV, located in Belgium, ZedHip/ZedKnee by Lexi Company, located in Japan [4], and HipPlan by Symbios, located in Sweden [6]. However, these software programs require manual segmentation of hip CT images, which is a more complex process than that using two-dimensional (2D) preoperative planning software. The average preoperative planning time using such software is approximately 24 minutes [7]. Recently, an artificial intelligence (AI)-based preoperative 3D planning system (Chang Mugu, Beijing, China) for THA was introduced, in which the size of femoral and acetabular prostheses can be analysed automatically

in real time; the average preoperative planning time needed for the study group was only approximately 5 minutes, significantly shortening the preoperative planning time. However, there have been no reports describing the utility of such preoperative planning systems for surgeons. Therefore, the aim of this study was to evaluate the matching rate of AI-based preoperative 3D planning systems and to investigate the value offered to surgeons with different levels of surgical experience.

2. Methods

2.1. Study population

This is a monocentric retrospective study. The study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University and was conducted in accordance with the Declaration of Helsinki. Because this study is a retrospective study, all patients are exempted from signing informed consent.

From August 2019 to October 2020, a total of 258 hips in 258 patients of 19–85 years of age with primary osteoarthritis and osteonecrosis of the femoral head (ONFH) who underwent cementless THA at The Third Hospital of Hebei Medical University were originally enrolled for the study, but 10 patients were excluded because it was not possible to collect all their data.

Additionally, 8 patients (8 hips) in whom dome screws were used were excluded. Thus, a total of 119 males and 121 females were ultimately included in this study. Patients with ONFH stages III and IV according to the Association Research Circulation Osseous classification and osteoarthritis grades III to IV according to the Kellgren–Lawrence classification were enrolled. Patients with a history of femoral surgery, severe osteoporosis and congenital or acquired proximal femoral deformity developmental dysplasia of the hip, femoral neck fracture and avascular necrosis after acetabular surgery, metabolic bone diseases, bacterial inflammation, or incomplete medical records or radiologic images were excluded.

2.2. Surgical process

All operations were performed by 2 surgeons, namely, 1 senior surgeon (experienced surgeon) and 1 junior surgeon (inexperienced surgeon), using a posterolateral approach. The surgeons had different levels of professional experience. We divided the patients into 2 groups based on the experience of the surgeon (group A: senior surgeon, group B: junior surgeon). One hundred and twenty THAs were performed by the senior surgeon (experienced surgeon), who completed approximately 1000 THAs annually. The remaining 120 THAs were performed by the junior surgeon (inexperienced surgeon), who completed fewer than 150 THAs annually. The profiles of the surgeons are presented in Table 6. We further subdivided the patients in each group into 2 groups according to whether AIHIP was used (group 1: YES, group 2: NO). The surgical procedures are described briefly as follows. The patient was placed in the lateral decubitus position with standard posterior support and anterior abdominal support placed between the lumbosacral region and pubic symphysis. After dislocation of the hip joint, femoral neck osteotomy was performed. Then, the acetabulum was exposed, and the acetabular component was implanted. Next, the Tri-lock stem was implanted following diaphyseal reaming using a reaming file. Finally, a ceramic head was used, and the joint was reduced. A Pinnacle acetabular cup and Tri-lock femoral stem were implanted in all cases (DePuy, USA). Patients were immediately allowed to attempt full weight-bearing on the day after the surgery (except those who had experienced periprosthetic fracture). The surgical technique was exactly the same in all patients, with the goal of obtaining 4° cup inclination and 15° anteversion as well as of controlling any impingement between the neck component and the cup, which could result in dislocation during 45° internal rotation and 90° flexion. Both groups of patients were given the same advice on movements to be avoided to prevent dislocation. Although we did not perform any CT scan measurements after surgery, the radiological results of the position of the implants were satisfactory in all these cases. All cups were press-fit fixation without dome screws. In 120 patients, minimally invasive THA was planned on the basis of an AI-based preoperative 3D planning system.

2.3. Outcomes

In this study, we compared the operative times in THA with and without the use of AIHIP performed by the same surgeon. We defined operative time as knife-to-skin until wound closure. To provide an indication of the level of perioperative blood loss, the

reduction in the haemoglobin level during the first 24 hours was assessed. We also measured the number of intraoperative radiations.

A CT scan of the hip region was obtained for each patient with a helical scanner (HiSpeed, GE Medical Systems, Milwaukee, WI) before the operation. The slice thickness varied between 3- and 5-mm during image acquisition, and the back-reconstruction parameters were 2 and 4 mm, respectively. The scanning range was from the anterior superior iliac spine to 10 cm below the lesser trochanter of the femur. CT images in DICOM format were transferred to AIHIP software. All preoperative planning was completed on the CT-based templating software AIHIP (Chang Mugu, Beijing, China), in which the size of femoral and acetabular prostheses were analysed automatically in real time. According to the anatomical characteristics of each patient, the model and placement position of the prosthesis were designed. The operation process was simulated, and postoperative X-ray film was generated in real time to assist doctors in evaluating the effect of surgery. The bone model was three-dimensionally reconstructed by computed tomography images before the operation. AIHIP can intelligently realize bone segmentation and correction, quickly and accurately select the size and location of prosthesis, automatically calculate the osteotomy height of femoral neck, length discrepancy of the bilateral legs, offset, acetabular cup coverage and provide other parameters to assist doctors in clinical decision-making (Fig.1). For each patient, a pelvic anterior–posterior radiograph was taken before the operation and prior to discharge. The patient's legs were placed together to control adduction/abduction, and then the hips were internally rotated 15° to overcome the natural anteversion of the femoral neck and provide a more accurate representation of the true medial and lateral dimensions of the metaphysis. We measured the difference in leg length, neck-shaft angle and femoral offset between the healthy side and the affected side with an anteroposterior radiographic view of the hip. Data are presented as absolute numbers. The leg length discrepancy (LLD) was measured as the difference in perpendicular distance in millimetres between a line passing through the lower edge of the teardrop points to the corresponding tip of the lesser trochanter of both sides. To evaluate the validity of preoperative templating, we also compared the predicted cup and stem sizes by the AIHIP with the used sizes operatively. The accuracy of preoperative planning was considered adequate for perfect matching or variance of \pm one size for the cup and stem compared with the selected implant during surgery. Final prosthetic component size from the operative record. All radiologic measurements were independently performed by 2 experienced orthopaedic surgeons using data obtained from the Picture Archiving and Communication Systems of our hospital and then averaged. To assess intra- and interobserver reproducibility, 20 patients were sampled randomly, and each measurement was independently measured and repeated after 1 week. All intraclass correlation coefficients, which are used to evaluate reproducibility, were >0.9 in this study.

2.4. Statistical analyses

Statistical analyses were performed with SPSS version 19.0 (IBM SPSS statistics, Chicago, IL, USA). All data were collected, and a database was constructed for statistical analysis. Descriptive statistics were applied for sex, age and BMI. Continuous variables are expressed as the mean \pm standard deviation. Chi-squared tests were used to compare categorical data. Statistical analyses were performed using Fisher's exact test and Mann–Whitney U test. Statistical significance was set at $p < 0.05$. A P-value <0.05 was considered significant.

3. Results

3.1. Demographic information

In this study, a total of 240 patients (119 males and 121 females) were included. The average age at the time of surgery was 52.03 ± 13.81 years (range, 19 to 85 years) in group A and 49.04 ± 12.86 years (range, 25 to 79 years) in group B, and the average BMI was 25.162 ± 3.753 kg/m² (range, 17.631 to 40.000 kg/m²) in group A and 25.817 ± 3.985 kg/m² (range, 16.706 to 40.123 kg/m²) in group B. There were 85 cases of primary unilateral ONFH and 35 cases of osteoarthritis in group A and 95 cases of primary unilateral ONFH and 25 cases of osteoarthritis in group B. In group A, 25 patients smoked and 28 patients consumed alcohol, and in group B, 22 patients smoked and 26 patients consumed alcohol. There were no other differences in the baseline characteristics between the two groups (Table 1).

3.2. Radiological measurements

In terms of postoperative outcomes, the average difference of neck-shaft angles of the healthy side and affected side in group A1 and group A2 were $3.870 \pm 3.034^\circ$ and $2.933 \pm 2.510^\circ$ ($P=0.088$), respectively. The average difference in the bilateral femoral offset between the healthy side and affected side for group A1 and group A2 was 6.152 ± 4.283 mm and 6.061 ± 4.043 mm, respectively, and the average LLD between the healthy side and affected side was 3.912 ± 2.673 mm and 3.937 ± 2.878 mm ($P=0.793$), respectively. The average difference of neck-shaft angles of the two sides in group B1 and group B2 were $5.450 \pm 4.443^\circ$ and $3.670 \pm 2.582^\circ$, respectively. Compared with group B1, group B2 had a smaller difference in the difference of bilateral neck-shaft angle ($P=0.025$). The average LLD between the healthy side and affected side of group B1 and group B2 was 6.070 ± 4.700 mm and 3.980 ± 3.043 mm, respectively. Compared with group B1, group B2 had a smaller LLD ($P=0.010$). The average difference in the bilateral femoral offset between the healthy side and affected side for group B1 and group B2 was 7.960 ± 4.503 mm and 6.199 ± 4.112 mm, respectively. Compared with group B1, group B2 had a smaller offset difference ($P=0.031$) (Table 2).

The matching rate of the acetabular prosthesis model in group A2 was 97%, and the matching rate of the femoral prosthesis model in group A2 was 95%. The matching rate of the acetabular prosthesis model in group B2 was 85%, and the matching rate of the femoral prosthesis model in group B2 was 87%. However, there was no significant difference between groups A2 and B2 in terms of the coincidence rate between the preoperative plan and the size realized in the operation on the acetabular side ($P=0.001$) and femoral side ($P=0.001$) (Table 3).

3.3. Clinical outcomes

In regard to the incidence of complications, no significant differences were found between groups A1 and A2 ($P=0.378$). However, a significant difference was found between groups B1 and B2 ($P=0.035$); the incidence of periprosthetic femoral fracture (13.3% vs. 3.3%, respectively, $P=0.048$) and the incidence of aseptic loosening (10.0% vs 0%, respectively, $P=0.036$) were also significantly different between these two groups. In addition, a significant difference in the incidence of complications was found between groups A1 and B1 ($P=0.010$); the incidence of periprosthetic femoral fracture (3.3% vs. 13.3%, $P=0.048$) and incidence of aseptic loosening (0% vs. 10.0%, $P=0.036$) were also significantly different between these two groups. No significant difference in the incidence of complications was found between groups A2 and B2 ($P=0.168$) (Table 4). The operation time was 51.400 ± 7.136 minutes in group A1 and 49.217 ± 6.028 minutes in group A2 ($P=0.085$), and it was 84.883 ± 9.579 minutes in group B1 and 73.667 ± 11.695 minutes in group B2 ($P=0.001$). The intraoperative radiation frequency was 1.100 ± 0.354 in group A1 and 1.017 ± 0.129 in group A2 ($P=0.094$), and the average decrease in haemoglobin (Hb) per 24 hours was 11.370 ± 6.866 g/L in group A1 and 11.090 ± 5.622 g/L in group A2 ($P=0.952$). The average decrease in Hb per 24 hours was 17.595 ± 8.260 g/L in group B1 and 14.848 ± 9.128 g/L in group B2 ($P=0.046$), the intraoperative radiation frequency was 3.233 ± 0.963 in group B1 and 1.600 ± 0.807 in group B2 ($P=0.001$) (Table 5).

4. Discussion

The main finding of this study was that the surgical planning performed with the AIHIP system is accurate and can help surgeons shorten the operation time and reduce the incidence of complications, especially for less experienced surgeons.

To understand whether this system is useful for achieving a precise model of the prosthesis and for the placement of the femoral stem prosthesis and acetabular cup regardless of the level of surgical experience, we analysed data from the patients after they were further subdivided into groups based on surgical experience (experienced and inexperienced surgeon groups) and investigated whether there were differences between these two groups with regard to surgical details, radiological evaluation and postoperative complications.

We found that there was no significant difference in the preoperatively planned and actual intraoperative implant size between groups A2 and B2. The concordance rate of the preoperatively planned and actual intraoperative implant size was 97% for cup size in group A2, and the concordance rate of the preoperatively planned and actual intraoperative implant size was 95% for stem size. The concordance rate of the preoperatively planned and actual intraoperative implant size was 87% in group

B2 for stem size, and the concordance rate of the preoperatively planned and actual intraoperative implant size was 85% for cup size. Previous studies on 3D templating have reported that the concordance rate of the preoperatively planned and actual intraoperative implant size ranges from 66 to 96% for cup size and 52 to 100% for stem size [6] [8-11], similar to the current findings. We think that this difference in concordance rates is related to the very different levels of training surgeons receive for this method as well as their experience level. Surgeons may not achieve accurate osteotomy, and the intended component positions of individual patients might be different. Although the match rates of these studies showed a high level of heterogeneity, the initial stability was excellent, and no complications occurred. In the current study, although few cases of implant cup size were mismatched, there were no cases in which the size was two sizes (4 mm) larger or smaller than the planned size. If the acetabular bone was quite hard and substantial resistance was felt with a smaller size of reamer than the planned size, a cup that was one size smaller was able to provide sufficient press-fit, whereas if the acetabular bone was found to be quite soft and less resistance was felt when using the same size of reamer as planned, a cup that was one size larger was deemed appropriate to provide better press-fit fixation. Therefore, the surgeon's judgement of the resistance felt during reaming and acetabular bone quality were possible reasons for cup size mismatch. Indeed, two factors—bone hardness and proximal femur torsion, which vary from 0° to 50° even if no major dysplasia is involved—may influence the introduction and final position of the stem inside the femoral canal [5, 12]. If the implant alignment differs from the planned alignment, the stem might be fixed between the medial proximal canal and lateral distal canal or between the anterior proximal canal and posterior distal canal. This fixation may affect the stem size. Based on the fact that stem alignment in the sagittal and coronal planes is related to an undersized stem, broach alignment should be checked intraoperatively when femoral canal broaching with a smaller broach than that chosen during 3D planning is difficult [13]. Lewinnek et al. suggested a safe zone of cup orientation to reduce the dislocation rate [14]. In all cases, the surgeon's intended position was within the "safe zone", as this is an important surgical goal of THA. The surgeons did not consider that cortical contact would be necessary to achieve stability with this implant and relied on the feel of rotational and axial stability to determine fit. Fixation was regarded as satisfactory when a series of moderate hammer blows did not change the final position of the femoral implant (Fig.2). Overall, the accuracy of the correct implant prosthesis for AI is good. Some prosthesis models that are predicted before the operation are different from the actual models used during operation. This may occur in situations when the surgeon cannot accurately carry out femoral neck osteotomy according to the preoperative planning, or it may be related to the operating habits of the surgeon. Therefore, intraoperative verification of the correct implant size, such as fluoroscopy, is still recommended.

The size of the acetabular prosthesis and femoral prosthesis has an important impact on the surgical effect. There was no significant difference in the overall incidence of complications between groups A1 and A2. There was also no significant difference in periprosthetic fractures, dislocation, aseptic loosening or thigh pain. This suggests that the guidance function of AI is limited for experienced surgeons with regard to the occurrence of complications. However, there was a significant difference in the overall incidence of complications between groups B1 and B2, which suggests that AI is beneficial for young surgeons with less surgical experience to reduce complication rates (Fig.3). We believe that this finding may be related to the tendency of young surgeons to have difficulty with patients with a large acetabulum, leading to rubbing and a poor osteotomy location without the use of AIHIP. Deviations in the position of the acetabular component can arise during impaction of press-fit components because of underreaming or oversizing [15]. AIHIP improves these outcomes and reduces the incidence of complications. Aseptic loosening remains the most important cause of long-term implant failure according to registry reports. Mismatching of the stem was found to be a risk factor for aseptic loosening [16]. We found significant differences between groups B1 and B2 in terms of periprosthetic fractures and aseptic loosening. This may be related to an improper prosthesis size. Fractures, poor implant positioning [17], heterotopic ossifications, septic or aseptic loosening [18], type of fixation and stem size [19] are related to thigh pain. Oversized cups in THA are a major risk factor for postoperative pain, especially anterior pain such as anterior iliopsoa impingement [20]. Persistent postoperative pain after THA has a reported incidence of 0-40% [21-25]. The incidence of thigh pain in groups A1, A2, B1 and B2 was 6.67%, 3.33%, 6.67% and 8.33%, respectively. In our study, there was no significant difference in the incidence of thigh pain among the groups. In addition, we found no significant difference in terms of dislocation between groups B1 and B2. Dislocation is due to a poor anteversion angle and small eccentricity. This may explain why the dislocation rate of the two groups was the same even though the difference in bilateral femoral offset between the two groups was different. A too large prosthesis size will lead to periprosthetic fractures, and a too small prosthesis will lead to early aseptic loosening [26]. The intraoperative rate was 3.3% for groups A1, A2 and B2, similar to

Berend et al's reported intraoperative rate of 4.4% using a tapered stem and posterior approach [27]. However, in our study, the aseptic loosening and periprosthetic fracture rates of group B1 were significantly higher than those of the other groups. This shows that AIHIP planning can reduce the incidence of periprosthetic fractures and aseptic loosening for young surgeons but provides little benefit for experienced surgeons. The 3D planning tool was able to identify regions with thick cancellous bone and high stability so that the stem could be adjusted to conserve those areas, making it possible to increase the contact surface (interface) between the femoral bone and the graft. Therefore, AIHIP planning can reduce these two complications, thus reducing the revision rate of patients. Young surgeons should consider using AI or other effective planning methods for preoperative planning. There was a significant difference in the overall incidence of complications between groups A1 and B1, which shows that the incidence of complications varies among surgeons with different experience levels, with more experienced surgeons having a lower revision rate [28]. We found that patients operated on by more experienced orthopaedic surgeons report better outcomes than patients operated on by less experienced surgeons. The incidence of complications of experienced surgeons is significantly lower than that of inexperienced surgeons, especially periprosthetic fracture and aseptic loosening. We believe that this is because experienced surgeons are able to access a good view of the anatomy at any time and can make adjustments according to the patient's soft tissue tension and other conditions during the operation. There was no significant difference in the overall incidence of complications between groups A2 and B2, which indicates that with the help of AI, the surgical skills of young doctors can be improved and the postoperative complication rate of inexperienced can be decreased to more closely match that of experienced surgeons. There was no significant difference in the overall incidence of complications between groups A1 and B2. There were also no significant differences in periprosthetic fractures, dislocation, aseptic loosening or thigh pain. Thus, with the help of AI, surgeons with little surgical experience can reach similar skill levels as experienced surgeons. Although the cause of these complications is multifactorial, the determination of prosthesis size before surgery using the AI-based preoperative 3D planning system may reduce these rates, especially in the case of inexperienced surgeons. AI-based preoperative 3D planning systems can improve the surgeon's ability and minimize outliers for this group of surgeons. To ensure the accuracy of preoperative planning, this study used a deep learning convolutional neural network (CNN) to intelligently segment the CT data of the hip joint. On the basis of improving the efficiency of surgical planning, precise segmentation was realized, and a computer algorithm was used to match the cup and the femoral stem, which effectively predicted the size of prosthesis needed in the operation. For inexperienced surgeons, the incidence of complications in patients in the AI groups was significantly less than that in patients in the non-AI groups.

An unequal length of the lower limbs will lead to a series of postoperative complications [29] and is the main cause of postoperative dissatisfaction [30]. No patient in our series complained of symptomatic LLD. In addition, we found no significant difference in the difference of length between the two lower limbs in groups A1 and A2, suggesting that AIHIP may play a limited role in controlling the length difference of the lower limbs for experienced surgeons. However, there was a significant difference in the difference of length between the two lower limbs in groups B1 and B2, which suggests that AI may play an important role in controlling the length difference of the lower limbs for inexperienced surgeons. The results showed that the use of AIHIP software for preoperative planning can effectively reduce postoperative LLD for inexperienced surgeons. Due to the short time frame, postoperative function was not evaluated, which needs to be confirmed by further research. We found that there was no significant difference in the difference in bilateral femoral offset between the two lower limbs in groups A1 and A2, suggesting that AI may play a limited role in controlling the difference in bilateral femoral offset among experienced surgeons. Furthermore, there was no significant difference in the difference of neck-shaft angle between the two lower limbs in groups A1 and A2, suggesting that AI may also play a limited role in controlling the difference in the neck-shaft angle of the lower limbs. However, we did find a significant difference in the difference in bilateral femoral offset between the two lower limbs in groups B1 and B2, indicating that AI may play an important role in controlling the difference in bilateral femoral offset of the lower limbs among inexperienced surgeons. We also found a significant difference in the difference of neck-shaft angle between the two lower limbs in groups B1 and B2, which suggests that AI may play an important role in controlling the difference in the neck-shaft angle as well. For this reason, we postulate that AI-based preoperative 3D planning is an attractive option for preoperative planning to improve the accuracy of hip reconstruction after THA, especially for leg length and offset.

There was no significant difference in the operation time between the A1 and A2 groups, but there were different trends, which indicated that AI might be helpful for experienced surgeons to reduce the operation time. The reliability of implant prediction allowed the nursing staff to prepare the appropriate implants before incision and reduced the use times of the reamer during the operation. In that way, loss of time and unnecessary traffic in the operating room during surgery can be minimized. There was no significant difference between groups A1 and A2 in the decrease in Hb in 24 hours after the operation or intraoperative radiation frequency, but there was a trend of difference, which suggesting that AI is helpful for doctors who already have surgical experience to reduce blood loss and radiation frequency during the operation. There was a significant difference in operation time between groups B1 and B2. This suggests that AI can help young doctors reduce the operation time, which may be related to the rapid selection of prostheses and the reduction in intraoperative radiation frequency. There was a significant difference in haemoglobin levels at 24 hours after the operation between groups B1 and B2. This may be related to the reduction in operation time and radiation frequency. Another factor may involve the reduction in surgical trauma as experience is gained and surgical technique improves, as there was a significant difference in radiation frequency between groups B1 and B2. Thus, the AI-based preoperative 3D planning system is a reliable technical tool that significantly reduces the blood loss and operation time of conventional freehand placement of the prosthesis in hip arthroplasty and is as accurate as the intraoperative prosthesis model.

To our knowledge, this study is the first to reveal the effect of AI-based preoperative 3D planning systems in THA on surgeons with different levels of experience. However, this study had a few limitations. First, we did not investigate functional outcomes in this study. Additional studies are required to examine whether the lower number of fitting prostheses achieved by the AI-based preoperative 3D planning system reduces postoperative complications and increases mid- and long-term survival of the implant in arthroplasty of the hip. Second, we only investigated the clinical outcomes at a single centre. These findings need to be validated in a larger cohort of surgeons across several other hospitals. Third, we evaluated only one design of implants for both the cup and stem in this study. Fourth, this system can only be used for preoperative planning of primary THA because the reference points were influenced by postoperative metal halation.

5. Conclusion

This study shows that the AIHIP is accurate and reduces the operation time, the degree of Hb decline, intraoperative radiation times and the surgical complications, and effectively reconstructs the normal anatomical structure of patients after operation. In conclusion, our study suggests that an AI-based preoperative 3D planning system for THA is a valuable adjunctive tool for young doctors and should routinely be performed preoperatively.

Abbreviations

Hb, haemoglobin; ONFH, osteonecrosis of the femoral head; AI, artificial intelligence; LLD, leg length discrepancy; 3D, three-dimensional; 2D, two-dimensional; BMI, body mass index; THA, total hip arthroplasty; CT, Computed Tomography.

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Review Board of the Third Hospital of Hebei Medical University.

Consent for publication

Written consents for publication were obtained from all study participants.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZBS, DXZ and HJ collected the data. LWA performed all preoperative planning and was the major contributor in writing the manuscript. YXW and LSK were responsible for analyzing the data. HYT reviewed the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Baseline patient characteristics in different groups.

General characteristics	Group A	Group B	Test statistics	P
Age (years)	52.03±13.81	49.04±12.86	-1.769	0.077
Gender				
Male	60	59	0.017	0.897
Female	60	61		
BMI (kg/m ²)	25.162±3.753	25.817±3.985	-1.199	0.230
Smoking status				
Yes	25	22	0.238	0.626
No	95	98		
Alcohol consumption				
Yes	28	26	0.096	0.757
No	92	94		
Indications				
ONFH	85	95	2.222	0.136
Osteoarthritis	35	25		
Side				
Left	70	63	0.826	0.363
Right	50	57		

Note: group A1: Senior surgeon without AIHIP group A2 Senior surgeon with AIHIP , group B1: Junior surgeon without AIHIP group B2 Junior surgeon with AIHIP

*Chi-square test, #Kruskal-Wallis test

Table 2. Radiological indicators of the prosthesis position in different groups (post-operation).

Radiological indicators	Group A1	Group A2	Z	P	Group B1	Group B2	Z	P
Discrepancy in leg length (mm)	3.912±2.673	3.937±2.878	-0.262	0.793	6.070±4.700	3.980±3.043	-2.593	0.010
Discrepancy of bilateral Neck-shaft angle	3.870±3.034	2.933±2.510	-1.706	0.088	5.450±4.443	3.670±2.582	-2.249	0.025
Discrepancy of bilateral femoral offsets	6.152±4.283	6.061±4.043	-0.068	0.946	7.960±4.503	6.199±4.112	-2.157	0.031

The discrepancy (absolute value) between the contralateral Neck-shaft angle / femoral offsets / and the affected side (the less obvious the difference is, the better the recovery is). The smaller the difference of the length of the lower limbs is, the better.

Anterior-posterior offset was defined as the vertical distance from the rotational center of the femoral head to the middle axis of the femur on the anterior-posterior view radiograph

In all patients, anteroposterior view examinations for the proximal femur were taken before and after the operation. The anteroposterior view radiograph, especially after surgery, was taken when patients were in standing posture with double support and a foot spacing equal to the shoulder width, while performing bilateral tiptoes lightly inward (15°).

Table3. Comparison of the difference between preoperative plan and the size realized in the operation

		Acetabular / Femoral Prosthesis Size									
		-4	-3	-2	-1	0	+1	+2	+3	+4	
Acetabular side											
	GroupA2	0	0	1	2	55	1	1	0	0	
	GroupB2	0	2	1	3	44	4	4	1	1	
	* χ^2	8.521									
	P	0.214									
Femoral side											
	GroupA2	0	0	1	2	54	1	1	1	0	
	GroupB2	0	1	2	2	46	4	3	1	1	
	* χ^2	5.868									
	P	0.608									

Note: group A2 Senior surgeon with AIHIP, group B2 Junior surgeon with AIHIP.

*Chi-square test

Table 4. Complications in different groups.

Complications	Group A1	Group A2	χ^2	P	Group B1	Group B2	χ^2	P
None	52	55	0.776*	0.378	40	50	4.444*	0.035
Yes	8	5			20	10		
Periprosthetic fracture	2	2	0.000*	1	8	2	3.927*	0.048
Dislocation	2	1	0.000*	1	2	3	0.000*	1
Aseptic loosening	0	0	-	-	6	0	4.386*	0.036
Thigh pain	4	2	0.175*	0.675	4	5	0.000*	1

Complications	Group A1	Group B1	χ^2	P	Group A2	Group B2	χ^2	P
None	52	40	6.708*	0.010	55	50	1.905*	0.168
Yes	8	20			5	10		
Periprosthetic fracture	2	8	3.927*	0.048	2	2	0.000*	1
Dislocation	2	2	0.000*	1	1	3	0.259*	0.611
Aseptic loosening	0	6	4.386*	0.036	0	0	-	-
Thigh pain	4	4	0.000*	1	2	5	0.607*	0.436

Complications	Group A1	Group B2	χ^2	P
None	52	50	0.261*	0.609
Yes	8	10		
Periprosthetic fracture	2	2	0.000*	1
Dislocation	2	3	0.000*	1
Aseptic loosening	0	0	-	-
Thigh pain	4	5	0.000*	1

Note: The prevalence of complications in each group is described in the parentheses. *Chi-square test

Table 5: Operation duration of Group A and Group B, decrease in hemoglobin (Hb) per 24 hours and Intraoperative radiation frequency.

	Group A1	Group A2	Z	P	Group B1	Group B2	Z	P
Mean duration of THA in mins	51.400±7.136	49.217±6.028	-1.725#	0.085	84.883±9.579	73.667±11.695	-5.087#	□ 0.001
Mean decrease in Hb/24 hours in mg/dl	11.370±6.866	11.090±5.622	-0.060#	0.952	17.595±8.260	14.848±9.128	-1.997#	0.046
Intraoperative radiation frequency	1.100±0.354	1.017±0.129	-1.675#	0.094	3.233±0.963	1.600±0.807	-7.569#	□ 0.001

#Kruskal-Wallis test

Table 6. Profiles of experienced and inexperienced surgeons

	Experienced surgeon	Inexperienced surgeon
Mean number of THAs per year	>1000	<150
Age (years)	55	35
Duration of clinical practice (years)	30	6

Figures

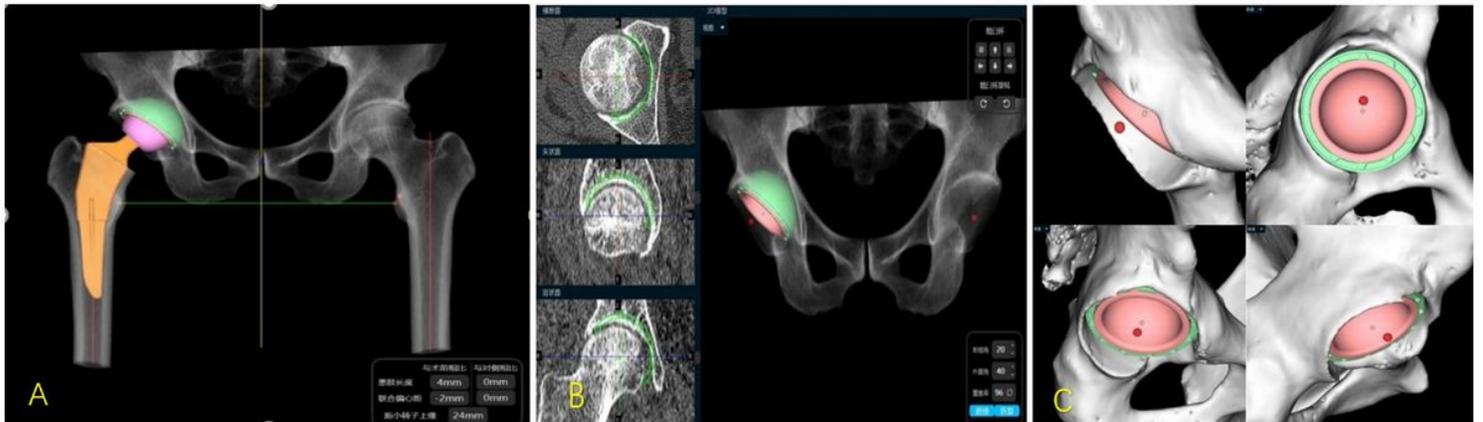


Figure 1

A: Preoperative planning of the femoral component. B and C: Preoperative planning of the acetabular component. The red dot represents the rotating centre of the femoral head.

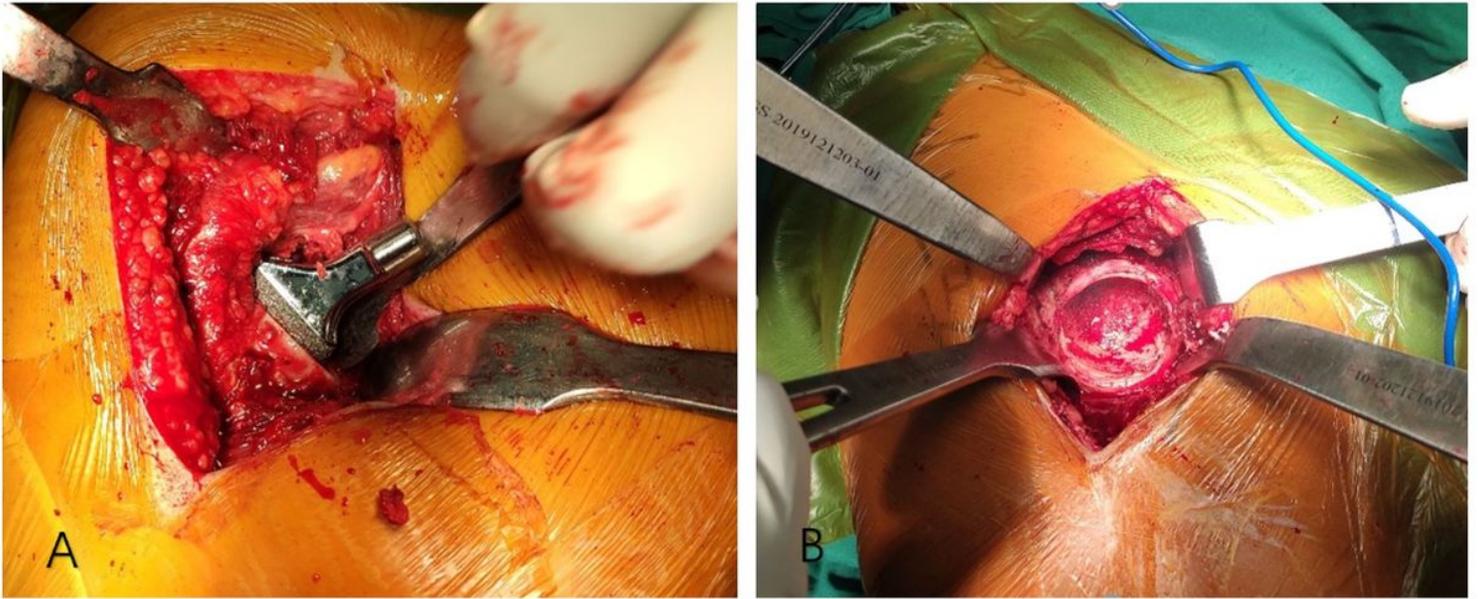


Figure 2

A Femoral stem prosthesis was implanted during the operation. B The ground acetabulum.



Figure 3

Complications due to improper prosthesis type. A B Intraoperative periprosthetic fracture. C Postoperative dislocation.