A Comparative Study of Patients’ Subjective Feelings Toward Total Hip Arthroplasty with Patient-Specific Instruments and Traditional Total Hip Arthroplasty

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Objective: To determine whether differences exist in patients’ subjective feelings, daily life, and surgical satisfaction between those who underwent surgery for developmental dysplasia of the hip (DDH) using patient-specific instruments (PSIs) and those who underwent traditional surgical total hip arthroplasty (THA).

Methods: We selected 30 adult patients with various types of DDH who underwent surgery during 2016–2017 at our hospital. The patients were divided into PSI surgery group and the traditional surgery group. All patients underwent follow-up, and we collected data on the Harris Hip Score, Oxford University Hip Score (OHS), Forgotten Joint Score (FJS-12), Visual Analogue Scale (VAS) score, patient satisfaction score, intraoperative surgical time, amount of bleeding and postoperative complications incidence for both groups. We then performed statistical analyses on the data.

Results: The Harris Hip Score, OHS, VAS score, patient satisfaction score, and mean bleeding volume did not differ statistically significantly (t-tests, P > 0.05). No statistically significant differences were found between surgical groups in the incidence of complication and sub-trochanteric osteotomy, or in the surgical side (chi-square tests, P > 0.05). For the experimental group, the FJS-12 score was 80.0 ± 12.0, and for the control group the score was 68.5 ± 16.1. The operative time of the experimental group was 138.4 ± 32.2 min, while that of the control group was 88.9 ± 26.8 min. The values of these data differed significantly (t-tests, P < 0.05).

Conclusions: The novel PSI designed by our group has certain advantages for the short-term subjective feelings of patients after THA, but it may cause prolonged operative times.

Key words: 3D printing; Patients’ feelings; Patient-specific instruments; Total hip arthroplasty

Introduction

Developmental dysplasia of the hip (DDH) is one of the most common hip diseases in pediatric orthopaedics worldwide, and the incidence of DDH is 4.9 per 1000 live births1. As an individual grows, DDH may lead to hip head palpitations, hip joint dislocation, and acetabular developmental disorders, and the end stage are osteoarthritis and osteonecrosis of the femoral head2. Presently, the typical treatment for adult DDH end-stage osteoarthritis is total hip arthroplasty (THA). THA has made rapid progress over the past few decades, but orthopaedic surgeons still face challenges3,4, such as patients with Crowe type III and IV dysplasia5. Common characteristics of those DDH patients include poor development and shallow flatness of the true

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acetabulum, increased acetabular anteversion, bone defects of
the anterior and lateral acetabular walls, a small femoral
head, a short and an obviously anteverted femoral neck, and
a small femoral bone marrow cavity. Therefore, orthopaedic
surgeons often encounter difficulties such as how to recon-
struct the acetabulum, determine the hip rotation center, and
ascertain whether bone grafting and sub-trochanteric osteo-
tomy are needed.

Studies have shown that a comprehensive preoperative
plan for patients with complex DDH can reduce the duration
of surgery and the incidence of intraoperative or postopera-
tive complications. Previously, the surgeon’s experience was
the most decisive factor in determining the position and ori-
entation of the acetabular component during surgery, which
could lack accuracy sometimes. Besides, the location of the
acetabular prosthesis may deviate from the ideal position
when the patient’s gesture changes during surgery.

To improve the surgical outcomes of THA in DDH,
some new surgical techniques have been used, such as three-
dimensional (3D)-printing technology, navigation tech-
niques, and patient-specific instruments (PSIs), to reduce the
uncertainty caused by the surgeon’s lack of experience.

Among them, PSIs have received extensive attention from
the medical community, especially in the field of joint
surgery. Currently, the design and production of PSIs
mainly rely on CT scanning, computer 3D design, preopera-
tive planning and 3D printing. Our team chose to combine a
3D-printed preoperative model with surgical-guide position-
ing technology. In preoperative surgical simulation, the 3D-
printed model could aid us in performing some key steps
using the computer, such as locating the true acetabulum,
positioning the acetabular rotation center, measuring and
reaming the acetabulum, performing the femoral neck osteo-
tomy, measuring the femoral isthmus medullary cavity, and
performing the sub-trochanteric osteotomy. The previous
work of Wang et al. showed that the PSI helps the surgical
team perform simulated surgery, notably improves the accu-
Juracy, certainty, and safety of the surgical procedure, and
facilitates communication between doctors and patients.

Furthermore, other studies have compared traditional sur-
gery and surgery using PSIs, including assessing the accuracy
of the prosthesis positioning, limb alignment, acetabular
anteversion angle, acetabular abduction angle, and joint
function. Most of these studies found that emerging PSI
procedures can improve the accuracy of artificial THA and
enhance surgical outcomes compared with the traditional
method.

Considering that no previous study has compared PSI
surgical procedures and traditional procedures in terms of
patients’ subjective feelings, herein we determined: (i) whether
differences existed in DDH patients’ subjective feelings, daily
life, and surgical satisfaction between those who received surgery using PSIs and those who underwent
traditional THA; and (ii) whether the new PSI procedure
elicited better subjective feelings and clinical effects than did
the traditional surgery from the patients’ perspectives.

**Patients and Methods**

**Inclusion and Exclusion Criteria**

We chose 15 patients as the PSI experimental group from
among those who accepted PSI surgery between April 2016
and June 2017 according to the inclusion criteria, and we
randomly selected 15 patients according to the inclusion
criteria as the control group from among those accepting
THA during the same period.

The inclusion criteria for patients consisted of:
(i) patients with Crowe’s DDH confirmed by imaging data;
(ii) they had a hip replacement in our hospital at least 1 year
previous to the study; (iii) they provided informed consent for
study; and (iv) the main evaluation indicators included Harris
Hip Score, Oxford University Hip Score (OHS), Forgotten
Joint Score (FJS-12), Visual Analogue Scale (VAS) score and
patient satisfaction score. The exclusion criteria were as fol-
loows: (i) age younger than 18 years; (ii) no obvious pain;
(iii) DDH combined with hip infection; (iv) suppurative hip
sequelae; (v) severe organ complications; and (vi) inability to
tolerate surgery.

The PSI surgical group included three men and
dwomen, and the traditional surgery group included four
men and 11 women. The age of the PSI group was
50.6 ± 13.9 years, and the age of the traditional surgery group
was 45.8 ± 13.9 years. In the PSI surgery group, five patients
were classified as having type I dysplasia according to the
Crowe classification, two had type III, and eight had type IV.
In the traditional surgery group, six patients had type I
dysplasia, three had type III, and six had type IV. In the PSI
surgery group, three patients received bilateral THA and
12 received unilateral THA, while in the control group, one
patient received bilateral THA and 14 received unilateral
THA. The preoperative characteristics that were compared
between the two patient cohorts included age, sex, Crowe clas-
sification, follow-up duration, Harris hip scores, and side of
surgery (Table 1). These parameters did not differ signifi-
cantly between the two patient cohorts (sex, Crowe classification,
and side of surgery were compared using chi-square tests; age,
follow-up duration, and Harris hip scores were compared
using t-tests). The study has been approved by the Institu-
tional Review Board (IRB) of the authors’ affiliated institu-
tions, and informed consent was obtained from all patients.

And use of the patients’ imaging data was permitted.

**Preoperative Preparation**

**Digital Operative Simulation**

All patients underwent a routine pelvic computed tomogra-
phy (CT) scan (0.6 mm thickness; Philips scanner, Eindhoven,
Netherlands), and the pelvic reconstruction data obtained
from CT scans of patients who underwent the PSI
surgical procedure were exported and preprocessed. We used
Mimics 19.0 software (Materialize, Leuven, Belgium) to digi-
tally reconstruct a 3D pelvic model. The digital reconstruc-
tion process for 3D-model simulation surgery is divided into
three steps. First, the pelvic position was standardized. The coronal plane was based on the relative position of the anterior and superior iliac spine and pubic tuberosity, and the standardized pelvic position was determined from the reference position of the pelvic coronal plane. Next, based on the patient’s acetabular features, a personalized assessment was made to determine the optimal position of the acetabular cup. Finally, optimal placement of the cup in the real acetabulum was simulated using the computer.

We used 3D, sagittal, coronal, and lateral views to confirm the optimal acetabular position. The evaluation criteria for the optimal acetabular position were as follows: (i) fitting edge: the diameter of the cup matched the actual peripheral boundary of the acetabulum; (ii) good cup bone coverage (we generally used 70% cup bone coverage as the standard); and (iii) the best center of rotation, which is generally based on the patient’s true position and leg length. If the contralateral acetabulum and femoral head were normal, we used the size and rotation center position as references.

**PSI Design**

After determining the ideal size and position of the acetabular cup, we designed the PSI. This device ensured that the surgeon could restore the position of the acetabular cup during surgery, as in the preoperative simulation. The previous work of Wang et al. provides detailed information on the PSI device. The device is divided into a fitter, an acetabular reamer guide plate, and an acetabular screw guide plate (Fig. 1), with the fitter fixed at the predetermined bone mark position. The acetabular reamer guide plate is further installed through the connection. If the acetabulum is to be fixed with screws, the acetabular screw guide plate is installed.

**Surgical Procedure**

**PSI Group Surgery**

The same experienced joint surgeon participated in the PSI design throughout the procedure and performed all surgeries. We selected the posterolateral approach with hip dislocation and full femoral head exposure. We followed the steps for using the PSI. First, the posterolateral portion of the acetabulum was completely exposed, the fitter was embedded in a specific site with a bony landmark (Fig. 2A). Second, the acetabular reamer guide plate was fixed onto the fitter, and two to three appropriately sized K-wires were placed into the fitter through the guide holes to fix the fitter (Fig. 2B). Then, the reamer was used to ream the acetabulum from small to large to mimic the preplanned model, shaping the ideal acetabulum as designed preoperatively (Fig. 2C). For severe acetabular defects, a structural bone graft was performed during surgery to provide more bone mass for the next revision surgery. The third step was to install the acetabular cup. Based on the preoperative simulation and intraoperative conditions, the surgeon judged whether an acetabular screw was needed to reinforce the cup. If necessary, the acetabular screw guide device was installed to the fitting connector, and methionine was used to label the safe area (Fig. 2D). Finally, the acetabular screws were installed into the labeled safe area (Fig. 2E) and the acetabular lining was installed to complete the surgery of the acetabular side of the hip (Fig. 2F). The surgical procedure was described in detail in the Video S1 attached to the manuscript.

**Traditional Group Surgery**

The same experienced joint surgeon performed the traditional surgery. After full exposure, the true position and rotation center of the acetabulum were determined based on the surgeon’s experience. We used an acetabular reamer to enlarge the true acetabulum and install a suitable cup. After ensuring the position and direction of the prosthesis, the acetabular screw was determined according to cup stability. Finally, we installed the acetabular lining and completed the surgical procedure on the acetabular side of the hip. For the cases in both surgical groups that could not be reduced after intraoperative soft tissue release, we performed a sub-trochanteric osteotomy.

**Data Collection**

All patients were followed for an average of 23 months (range, 14–35 months). The average follow-up time was 23.4 months in the PSI group and 23.7 months in the traditional surgery group. The data we collected are as follows:

**Harris Hip Score (HHS)**

The HHS was developed to assess the results of hip surgery, and evaluate various hip disabilities and methods of treatment in an adult population. It assesses symptoms that are characteristic to this condition such as pain, loss of mobility, and muscle function. The domains covered are pain, function, deformity, and range of motion, and each item has a unique numerical scale that corresponds to descriptive response options. The maximum score of HHS is 100. The higher the HHS, the less dysfunction. In the present study, we collected the HHS before and after surgery, and the data is presented in Tables 1 and 2.

**Oxford University Hip Score (OHS)**

The OHS is another scale to evaluate the outcome after total hip replacement (THR) by measuring patients’ perceptions in addition to surgery, which assesses pain (six items) and function (six items) of the hip in relation to daily activities such as walking, dressing, sleeping, etc. Each question has 4 answers to select, correspondingly 0–4 scores (worst to best). The overall scores range from 0 to 48, and 48 represents the best score. The higher the score, the better prospects and the lower the dysfunction. In this study, we collected the OHS after surgery, as shown in Table 2.

**Forgotten Joint Score (FJS-12)**

The FJS-12 comprise measures for the assessment of joint-specific patient-reported outcome (PRO): the patient’s ability
Joint awareness can be simply defined as any unintended perception of a joint. In this questionnaire, 12 questions are answered with either never, almost never, seldom, sometimes, mostly, and “not relevant to me”, corresponding from 0 to 4 points. Total points are calculated according to the average score of all answered questions and then multiplied by 25 into centesimal system (0–100 points). Higher scores refer to better outcome, which means a better “forgotten” index of the joint and a low degree of awareness. We collected the FJS after surgery, as shown in Table 2.

Visual Analogue Scale (VAS) Score
The pain VAS score\(^2\) is a unidimensional measure of pain intensity, which has been widely used in diverse adult populations. The VAS scale we used is a straight horizontal line of fixed length, 100 mm. The ends are defined as the extreme limits of the pain to be measured orientated from the left (0) to the right (10). We collected the VAS score after surgery, as shown in Table 2.

Patient Satisfaction Score
The patient satisfaction score is a scale totally based on patients’ subjective feelings about their artificial joint after total hip arthroplasty after at least 1 year. Responses are measured on a scale of 1 to 10, with 10 being the best score. Higher scores refer to better satisfaction about this surgical process. We collected the patient satisfaction score after surgery, as shown in Table 2.

Operative Time
The data of surgery time we collected from surgical records are from skin inclusion until surgical closure, which could reflect the proficiency of the operators for two surgical methods, and the unit of time calculation is minutes. We collected all patients’ data and did the statistical analysis, and the representation of results are shown in Table 2.

Amount of Bleeding
We defined the amount of bleeding in this study as the intra-operative blood loss\(^3\). We weigh the used compresses

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### Table 1: Comparison of demographic characteristics between the two groups

| Variable                              | Patient-specific instrument (n = 15) | Conventional instrument (n = 15) | \(P\) value |
|---------------------------------------|-------------------------------------|----------------------------------|-------------|
| Age (year)                            | 50.6 ± 13.9                         | 45.8 ± 13.9                      | >0.05       |
| Sex, n (%)                            |                                      |                                  | >0.05       |
| Men                                   | 3 (20.0%)                           | 4 (26.7%)                        |             |
| Women                                 | 12 (80.0%)                          | 11 (73.3%)                       |             |
| Crowe Classification                   |                                      |                                  | >0.05       |
| I                                     | 5 (33.3%)                           | 6 (40.0%)                        |             |
| II                                    | 0 (0.0%)                            | 0 (0.0%)                         |             |
| III                                   | 2 (13.3%)                           | 3 (20.0%)                        |             |
| IV                                    | 8 (53.3%)                           | 6 (40.0%)                        |             |
| Harris hip scores (pre-operative)     | 66.0 ± 8.7                          | 69.2 ± 8.3                       | >0.05       |
| Follow-up time (month)                | 23.7 ± 3.7                          | 25.4 ± 4.0                       | >0.05       |
| Unilateral/bilateral                  |                                      |                                  |             |
| Unilateral                            | 3 (20.0%)                           | 1 (6.7%)                         |             |
| Bilateral                             | 12 (80.0%)                          | 14 (93.3%)                       |             |

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Fig. 1. Inspection of patient-specific instruments designed by us. (A) the bony landmark and fitter. (B) an acetabular reamer guide plate assembled on the fitter and the zone for autografted bone. (C) an acetabular screw guide plate assembled on the fitter to determine the safe area for screw.
and record the amount of blood in the suction bottle and the filtrated drainage blood which was recycled and transfused to patients by self-blood transfusion equipment during operation to calculate intra-operative blood loss. We did the statistical analysis, and the results are shown in Table 2.

**Postoperative Complication Incidence**

The postoperative complication of this study included revision, dislocation, wound healing, nerve injury, and thigh pain. The number of patients with complications divided by the number of each group is the incidence of postoperative complication. The results are shown in Table 2.

**Statistical Analysis**

The data are expressed as the mean and range. Chi-square test was used to analyze the difference of sub-trochanteric osteotomy and complications, and t-test was used to analyze the difference of Harris Hip Score, Oxford Hip Score, Forgotten Joint Score, VAS Score, Patient satisfaction score, operative time and amount of bleeding between two groups. Statistical analyses were performed using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA). P values less than 0.05 were considered statistically significant.

**Results**

**Follow-up**

The follow-up time of all patients was at least 1 year. The follow-up time of patients who accepted PSI surgical treatments was $23.7 \pm 3.7$ months vs $25.4 \pm 4.0$ months of patients who accepted traditional surgery. The difference was not significant ($F = 1.114, P = 0.232$).

**General Results**

Five patients in the experimental group and two patients in the control group received sub-trochanteric osteotomies, but the difference was not statistically significant ($X^2 = 1.677, P = 0.195$). The bleeding volume of the experimental group was $470.0 \pm 134.7$ mL vs $453.3 \pm 147.0$ mL of the control group, and the difference was not statistically significant ($F = 0.008, P = 0.748$). The operative time for the experimental group was $138.4 \pm 32.2$ min, while the mean operative time for the control group was $88.9 \pm 26.8$ min, which was

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**Fig. 2** The steps for using the patient-specific instruments. (A) the superolateral portions of the acetabulum were exposed, and the fitter was embedded. (B) the acetabular reamer guide plate was fixed onto the fitter, and K-wires were placed into the fitter. (C) the reamer was used to ream the acetabulum. (D) the acetabular screw guide device was installed, and methionine was used to label the safe area. (E) the acetabular screws were installed. (F) the acetabular lining was installed.
TABLE 2 Comparison of postoperative results between the two groups

| Variable                        | Patient-specific instrument (n = 15) | Conventional instrument (n = 15) | P value |
|---------------------------------|-------------------------------------|---------------------------------|---------|
| Subtrochanteric Osteotomy, n (%)|                                    |                                 | >0.05   |
| Yes                             | 5 (33.3%)                           | 2 (13.3%)                       |         |
| No                              | 10 (66.7%)                          | 13 (86.7%)                      |         |
| Harris Score                    |                                    |                                 |         |
| 3 months postoperatively        | 81.7 ± 2.5                          | 79.5 ± 3.8                      | >0.05   |
| 2 years postoperatively         | 91.8 ± 6.1                          | 91.3 ± 4.6                      | >0.05   |
| Oxford Hip Score               | 16.3 ± 3.8                          | 16.5 ± 2.8                      | >0.05   |
| Forgotten Joint Score          | 80.0 ± 12.0                         | 68.5 ± 16.1                     | 0.035   |
| Visual Analogue Score          | 0.5 ± 0.6                           | 0.7 ± 0.7                       | >0.05   |
| Satisfaction Score             | 9.1 ± 0.8                           | 8.7 ± 1.0                       | >0.05   |
| Operative Time, n (min)        | 138.4 ± 32.2                        | 88.9 ± 26.8                     | <0.001  |
| Amount of bleeding             | 470.0 ± 134.7                       | 453.3 ± 147.0                   | >0.05   |
| Complications, n (%)           |                                    |                                 | >0.05   |
| Revision                       | 0                                   | 0                               |         |
| Dislocation                    | 0                                   | 0                               |         |
| Wound Healing                  | 0                                   | 0                               |         |
| Nerve Injury                   | 0                                   | 0                               |         |
| Thigh Pain                     | 1 (6.7%)                            | 1 (6.7%)                        |         |

statistically significant \((F = 0.004, P < 0.001)\). That indicated operative time of PSI group is 55.7% longer than control group.

**Functional Evaluation**

**Harris Hip Score (HHS)**

The HHS score of the experimental group was 81.7 ± 2.5 at 3 months postoperatively and 91.8 ± 6.1 at the last follow-up, both of which were significantly better than 66.0 ± 8.7 preoperatively \((P < 0.001, t = -6.308 \text{ and } P < 0.001, t = -13.596)\). And the control group HHS was 79.5 ± 3.8 at 3 months postoperatively and 91.3 ± 4.6 at the last follow-up, both of which were significantly better from 69.2 ± 8.3 preoperatively \((P = 0.002, t = -3.850, P < 0.001, t = -9.822)\). The difference of pre-operative HHS between the two groups was not significant \((F = 0.004, P = 0.322)\), neither at 3 months \((F = 1.522, P = 0.077)\) nor at almost 2 years \((F = 1.190, P = 0.815)\) follow-up.

**Oxford University Hip Score (OHS)**

The OHS of the experimental group was 16.3 ± 3.8 vs 16.5 ± 2.8 of the control group, and the difference was not significant \((F = 2.354, P = 0.871)\).

** Forgotten Joint Score (FJS-12)**

The FJS-12 score was 80.0 ± 12.0 for the experimental group vs 68.5 ± 16.1 for the control group. There was a statistical difference between these two groups \((F = 0.582, P = 0.035)\), and the PSI group is more than the control group by 16.8%.

**Visual Analogue Scale (VAS) score**

The VAS score of the experimental group was 0.5 ± 0.6 vs 0.7 ± 0.7 of the control group, and the difference was not significant \((F = 0.248, P = 0.597)\).

**Patient Satisfaction Score**

The patient satisfaction score of the experimental group was 9.1 ± 0.8, and the control group was 8.7 ± 1.0. The difference was not significant \((F = 0.600, P = 0.234)\).

**Complications**

Mild thigh pain occurred in one patient in each group during movement. However, no patients required non-steroidal anti-inflammatory drugs or opioid analgesics for pain relief at the last follow-up. No dislocation, nerve damage, or delayed wound healing occurred in either group. No revision occurred in either group. Table 2 presents the follow-up outcomes of the two patient groups.

**Discussion**

PSIs and 3D printing, widely used in clinical medicine, aim to provide personalized medical services for patients to make clinical treatment more individualized and precise. Surgeons have combined 3D-printed surgical models with patient-specific instruments, which have been gradually incorporated to assist with preoperative design, virtual surgery, and intraoperative surgical procedures. PSIs and 3D printing aim to provide personalized medical services for patients to make clinical treatment more individualized and precise.

The PSIs used in this study were original and unique. Our team designed the PSI guide device for feasible bone positioning, and the molds interlocked together, limiting the maximum size and depth of the acetabular reamer. Thus, we ensured the accuracy of the true position and the acetabular reamer’s size, angle, and depth. In addition, the safety zones of the acetabular screws were determined, and the position and direction of the screws were planned during the preoperative simulation, thus preventing damage to the nerve and blood vessel when the screws were installed during the operation. Therefore, the PSI guide device designed in this study
is original and innovative and ensures surgical accuracy and safety. Comparing the clinical effects of PSI surgery with traditional surgical procedures is a common concern for orthopaedic surgeons, although the use of PSI procedures has accelerated in recent years. Spencer-Gardner et al. compared the accuracy of PSI and traditional surgery based on the position of the acetabular prosthesis, and suggested that using the PSI procedure allowed for more accurate prosthetic positioning than traditional surgery. Zhang et al. showed that the accuracy of specific 3D templates in hip arthroplasty was significantly higher than that in traditional surgery.

However, no research has ever compared patients’ subjective feelings between THA using a PSI and traditional surgery. This study investigated whether patients who received THA via the PSI procedure had superior subjective feelings and improved quality of life compared with patients who received traditional THA during a short-term follow-up. We used the Harris Hip Score, OHS, FJS-12, VAS, and patient satisfaction scores to evaluate the patients’ subjective feelings. The results showed no significant differences in the Harris Hip Score, OHS, VAS, or patient satisfaction scores between the PSI and traditional surgery groups; however, the FJS-12 scores of patients who underwent the PSI procedure were significantly higher than those of patients who underwent traditional surgery. In addition, the patient satisfaction scores of the PSI surgery group were slightly higher than those of the traditional surgery group, although the difference was not statistically significant. These results indicate that the PSI surgery group had a greater advantage in terms of patients’ subjective feelings, and the emerging PSI surgical procedure provided a better postoperative experience for these patients.

Besides, the results of the present study revealed that the operating time for the PSI group was significantly longer than that of the traditional surgery group, indicating that the surgeon performing the PSI surgery needed more time to complete the exposure and confirm the bony mark as well as to install the guide plate. Prolonged surgical times inevitably lead to adverse impacts on patients, such as prolonged intraoperative anesthesia, increased intraoperative blood loss, and increased risk of infection. Surace et al. investigated the relationship between the operative times of 89,802 hip arthroplasty procedures and their associated short-term postoperative complications and reported that the longer the operating time, the higher the risks of infection, readmission, second operations, wound splitting, and blood transfusion. Wills et al. followed 103,044 patients who underwent THA operation and showed that for each additional 10 min of surgical time, the incidence of surgical site infection increased by 7%. We believe that this operational time will gradually be shortened as surgical experience increases.

In the present study, we found that patients who underwent the PSI surgical procedure had better short-term subjective experiences than those who underwent the traditional surgical procedures, but prolonged operative time may cause some complications post-surgery. The Harris Hip Score, OHS, and VAS scores showed no differences between the PSI and traditional groups in our study, indicating that the PSI procedure did not significantly improve the surgical outcomes. Therefore, the PSI procedure may not be a necessary option for experienced joint surgeons. In addition, the PSI surgery costs more than traditional surgery does. Each PSI surgery costs at least 6500 RMB more than traditional surgery, including design of preoperative 3D models, preoperative surgical procedure simulation, and production and sterilization of acetabular guide plate, which is an economic burden for patients in poor financial situations. As a result, popularizing PSI surgery may face some difficulties in the future.

This study has some limitations. As the retrospective study, the patients were not randomized, which might result in bias within the study. Data of pre-operative patient’s subjective feelings were not collected, so we couldn’t totally ensure the pre-operative equality of general background between two groups. Besides, the sample size for the follow-up research was small, and the follow-up duration was comparatively short. Further prospective studies with larger sample sizes and longer follow-up times are required to investigate the value of the clinical application of PSIs.

The novel PSI designed by our group has certain advantages regarding patients’ subjective feelings after THA in the short term, but these may cause prolonged operating times. Therefore, for experienced joint surgeons, the PSI procedure may be unnecessary.

Disclosure
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Supporting Information
Additional Supporting Information may be found in the online version of this article on the publisher’s web-site:

Video S1 A simulation in computer of PSI design and application in surgery

Reference
1. Woodacre T, Ball T, Cox P. Epidemiology of developmental dysplasia of the hip within the UK: refining the risk factors. J Child Orthop, 2016, 10: 633–642.
2. Wang D, Li LL, Wang HY, Pei FX, Zhou ZK. Long-term results of Cementless Total hip Arthroplasty with subtrochanteric shortening osteotomy in Crowe type IV developmental dysplasia. J Arthroplasty, 2017, 32: 1211–1219.
3. Zeng M, Hu Y, Leng Y, et al. Cementless total hip arthroplasty in advanced tuberculosis of the hip. Int Orthop, 2015, 39: 2103–2107.
4. Xu J, Zeng M, Xie J, Wen T, Hu Y. Cementless total hip arthroplasty in patients with ankylosing spondylitis: a retrospective observational study. Medicine, 2017, 96: e5813.
5. Lei P, Hu Y, Cai P, Xie J, Yang X, Wang L. Greater trochanter osteotomy with cementless THA for Crowe type IV DDH. Orthopedics, 2013, 36: e601–e605.
6. Chen M, Luo ZL, Wu KR, Zhang XQ, Ling XD, Shang XF. Cementless total hip arthroplasty with a high hip center for Hartofilakidis type B developmental Dysplasia of the hip: results of midterm follow-up. J Arthroplasty, 2016, 31: 1027–1034.
7. The B, Diercks RL, van Ooijen PM, van Horn JR. Comparison of analog and digital preoperative planning in total hip and knee arthroplasties. A prospective study of 173 hips and 65 total knees. Acta Orthop, 2005, 76: 78–84.
8. Inoue D, Kabata T, Kimura H, Tsuchiya H. A prospective clinical trial to assess the accuracy of an MR-based patient-specific acetabular instrument guide in total hip arthroplasty. Eur J Orthop Surg Traumatol, 2019, 29: 65–71.
9. Xu J, Li D, Ma RF, Barden B, Ding Y. Application of rapid prototyping pelvic model for patients with DDH to facilitate Arthroplasty planning: a pilot study. J Arthroplasty, 2015, 30: 1963–1970.
10. Romanowski JR, Swank ML. Imageless navigation in hip resurfacing: avoiding component malposition during the surgeon learning curve. J Bone Joint Surg Am, 2008, 90: 65–70.
11. Liu Q, Zhou YX, Xu HJ, Tang J, Guo SJ, Tang QH. Safe zone for transacetabularscrew fixation in prosthetic acetabular reconstruction of high developmental dysplasia of the hip. J Bone Joint Surg Am, 2009, 91: 2880–2885.
12. Ito H, Tanaka S, Tanaka T, Oshima H, Tanaka SA. Patient-specific instrument for femoral stem placement during total hip arthroplasty. Orthopedics, 2017, 40: e374–e377.
13. Schwarzkopf R, Schnaser E, Nozaki T, Kaneko Y, Gillman MJ. Novel, patient-specific instruments for acetabular preparation and cup placement. Surg Technol Int, 2016, 26: 309–313.
14. Musil D, Stehlik J, Abrman K, Held M, Sadovsky P. Use of patient specific instruments at total knee arthroplasty. One-year results of a prospective randomised study. Acta Chir Orthop Traumatol Cech, 2016, 83: 175–181.
15. Li B, Lei P, Liu H, et al. Clinical value of 3D printing guide plate in core decompression plus porous bioceramics rod placement for the treatment of early osteonecrosis of the femoral head. J Orthop Surg Res., 2018, 13: 130.
16. Wang C, Xiao H, Yang W, et al. Accuracy and practicability of a patient-specific guide using acetabularsuperolateral rim during THA in Crowe II/III DDH patients: a retrospective study. J Orthop Surg Res., 2019, 14: 19.
17. Mainard D, Barbier D, Knafo Y, Belleville R, Mainard-Simard L, Gross JB. Accuracy and reproducibility of preoperative three-dimensional planning for total hip arthroplasty using biplanar low-dose radiographs: a pilot study. Orthop Traumatol Surg Res., 2017, 103: 531–536.
18. Small T, Krebs V, Molloy R, Bryan J, Klika AK, Barsoum WK. Comparison of acetabular shell position using patient specific instruments vs. standard surgical instruments: a randomized clinical trial. J Arthroplasty, 2014, 29: 1030–1037.
19. Yang Y, Zuo J, Liu T, Xiao J, Liu S, Gao Z. Morphological analysis of true acetabulum in hip dysplasia (Crowe Classes IV) via 3-D implantation simulation. J Bone Joint Surg Am, 2017, 99: e92.
20. Nilssdotter A, Bremslander A. Measures of hip function and symptoms: Harris hip score (HHS), hip disability and osteoarthritis outcome score (HOOS), Oxford hip score (OHS), Lequesne Index of severity for osteoarthritis of the hip (LI), and American Academy of orthopedic surgeons (AAOS) hip and knee questionnaire. Arthritis Care Res (Hoboken), 2011, 63: S260–S267.
21. Zheng W, Li J, Zhao J, Liu D, Xu W. Development of a valid simplified Chinese version of the Oxford hip score in patients with hip osteoarthritis. Clin Orthop Relat Res, 2014, 472: 1545–1551.
22. Cao S, Liu N, Han W, et al. Simplified Chinese version of the forgotten joint score (FJS) for patients who underwent joint arthroplasty: cross-cultural adaptation and validation. J Orthop Surg Res, 2017, 12: 6.
23. Aun C, Lam YM, Collett B. Evaluation of the use of visual analogue scale in Chinese patients. Pain, 1986, 25: 215–221.
24. Miao K, Ni S, Zhou X, et al. Hidden blood loss and its influential factors after total hip arthroplasty. J Orthop Surg Res, 2015, 18: 36.
25. Spencer-Gardner L, Pierepoint J, Topham M, Bare J, McMahon S, Shimmim AJ. Patient-specific instrumentation improves the accuracy of acetabular component placement in total hip arthroplasty. Bone Joint J, 2016, 98-B: 1342–1346.
26. Zhang YZ, Chen B, Lu S, et al. Preliminary application of computer-assisted patient-specific 3D electronics for acetabular navigation template for total hip arthroplasty in adult single development dysplasia of the hip. Int J Med Robot, 2011, 7: 469–474.
27. Suraic P, Sultan AA, George J, et al. The association between operative time and short-term complications in Total hip Arthroplasty: an analysis of 89,802 surgeries. J Arthroplasty, 2015, 30: 1963–1968.
28. Wills BW, Sheppard ED, Smith WR, et al. Impact of operative time on early joint infection and deep vein thrombosis in primary total hip arthroplasty. Orthop Traumatol Surg Res, 2018, 104: 445–448.