Acta Orthop. Belg., 2018, **84**, 430-435

ORIGINAL STUDY

Pelvic height planning versus conventional templating in preoperative planning of acetabulum cup size for THA

Dong Wang, Huawu Zhang, Shui Sun, Yonggang Zhou, Jiying Chen, Libo Hao

From the Department of Orthopaedics, Chinese People's Liberation Army General Hospital, 301 Orthopaedic Hospital, Beijing, China

This study aimed to compare the accuracy of pelvic height planning vs. the conventional templating method for acetabulum cup measurement. A total of 200 consecutive patients undergoing primary total hip arthroplasty (THA) were randomly grouped as follows: group A, accepting conventional templating; group B, accepting pelvic height planning. Preoperative measurement of the acetabular cup was performed with conventional templating and pelvic height planning, respectively. There were 57 cases with the same size or with one type size discrepancy, 49 with two type size discrepancies, and 14 with three type size discrepancies in group A. There were 145 cases with the same size or one type size discrepancy, 20 with two type size discrepancies, and 3 type size discrepancies in group B. The mean difference between the planned size and actual cup size was 2.58 ± 0.89 mm (group A) vs. 1.38 ± 1.22 mm (group B). Therefore, pelvic height planning is reliable for use in preoperative planning compared with conventional templating.

Keywords : acetabulum cup ; Conventional Templating ; Pelvic Height Planning.

INTRODUCTION

Total hip replacement (total hip arthroplasty, THA) is one of the most common and successful orthopaedic interventions *(15)*. For patients with hip pain due to a variety of conditions, such as osteonecrosis of the femoral head, THA provides significant pain relief, restores function, enhances mobility and improves quality of life *(10)*. Despite the efficacy of THA, complications can occur, including hip dislocation and femoral fractures, resulting in poor functional outcomes *(12,23,24)*. Since the variety of designs and the number of sizes of the prostheses for THA have increased considerably, THA has become a more complex procedure *(17)*. Currently, preoperative planning has been an integral part of THA and has been demonstrated to facilitate precise, efficient, and reproducible THAs *(22)*. Studies have emphasized the importance of preoperative radiographs in choosing the type and size of prosthesis components,

■ Dong Wang[1].
■ Huawu Zhang[1].
■ Shui Sun[1].
■ Yonggang Zhou[2].
■ Jiying Chen[2].
■ Libo Hao[2].
[1]*Department of Orthopedics, Shandong Provincial Hospital Affiliated to Shandong University, Jinan, Shandong, China.*
[2]*Department of Orthopaedics, Chinese People's Liberation Army General Hospital, 301 Orthopaedic Hospital, Beijing, China.*
Correspondence : Libo Hao, Department of Orthopaedics, Chinese People's Liberation Army General Hospital, 301 Orthopaedic Hospital, 28 Fuxing Road, Haidian District, Beijing 100853, China. Tel and Fax: 010-66938304
E-mail : libowell@126.com

No benefits or funds were received in support of this study. The authors report no conflict of interests.

achieving the appropriate orientation and position of the components, equalizing leg length, and reducing the duration and complications from the operation *(2,11)*.

Numerous studies have reported the utility of preoperative planning with overlying templates. Templating has been conducted using drawings on transparencies of appropriately magnified implants, and these templates are generally used on anteroposterior (AP) and axial X-rays to assess the appropriate size of implant *(13)*. Templating can help selection of correct size of implants, reduce the risk of periprosthetic fracture *(16)*, help restore both the femoral offset *(6,26)* and leg length to avoid dislocation and limping *(4,18)*. It is not surprising that new technologies and several software packages have been introduced for preoperative templating on digital images to aid physicians in more precise surgical planning *(28)*. However, digital templating requires the availability of the digital templating software on numerous workstations and some hospitals may incur a large expense for these technologies *(19)*. Therefore, the conventional, template-over-X-ray procedure (simply referred to as templating or template planning) remains the gold standard technique *(29)*. Any new method should be compared with conventional template planning in terms of repeatability and accuracy. Ranawat et al. proposed using the true acetabular region, as the area of the cup position and size is chosen to fit the anteroposterior acetabular diameter *(21)*. Recently, a rather simple method on the basis of plain anteroposterior X-rays of the pelvis was published *(3,8)*. Some studies propose that there is no difference in predicting the final component selection during surgery between pelvic height planning and conventional templating *(5,14)*. However, the validity and reliability of pelvic height planning has not been compared with conventional templating techniques.

The present study analysed the clinical data of patients who accepted different methods of measurements for the acetabulum cup: pelvic height planning vs. conventional templating before primary THA. The purpose of this study was to compare the precision and utility of pelvic height planning vs. conventional templating. This study focused on the predictability of the implant size. We anticipate that the results will contribute to the preoperative planning of THA.

MATERIALS AND METHODS

Between July 2014 and December 2014, a total of 200 consecutive patients who underwent primary THA for primary osteoarthritis (74 cases) or femoral head necrosis (126 cases) were analysed in the Joint Department of People's Liberation Army (PLA) General Hospital. Primary THA was performed on a total of 288 hips, of which 112 cases underwent unilateral total hip replacement (112 hips) and 88 cases underwent bilateral total hip replacement (176 hips). These 200 patients were randomly grouped into 2 groups, group A accepting conventional templating (100 patients, 120 hips) and group B accepting pelvic height planning (100 patients, 168 hips). This study was conducted with the approval of the Committee for Ethics of the Chinese PLA General Hospital. All patients provided written informed consent for surgical treatment and pathological examination, according to institutional guidelines.

As shown in Table 1, there were 134 men and 66 women, and the average age of these patients ranged from 26 to 78 years. There were no significant differences between these 2 groups with regard to the age, gender or the body mass index (Student's t-test, $p > 0.05$). The inclusion criteria were as follows: (1) no obvious pelvic deformity; (2) a standard X-ray film of the pelvis; (3) no incorporated lower extremity (including knee, ankle) severe lesions or valgus deformity; and (4) all operations were to be conducted by physicians who participated in this study. A cementless cup and stem (Link, Hamburg, Germany) were used in all cases.

Standard AP radiographs of the pelvis and lateral radiographs of the hip were taken preoperatively and postoperatively. Patients were lying on their back and with the lower limbs in a neutral position, and the patient was palpated on their surgical side for measurement of the large rotor. A Marker of known diameter to the photography was set in a fixed position and as a magnification evaluation and correction for reference.

Table I. — Comparison of clinical data between the two groups

Group	Age (years)	Gender (M/F)	Pelvic height (cm)	Weight (Kg)
A	61.4 ± 14 (26-78)	64M/36F	173 ± 10.7 (157-184)	72.3 ± 13.6 (53-87)
B	59.8 ± 15 (30-73)	70M/30F	172 ± 9.2 (154-185)	71.6 ± 15.4 (53.2-85)

For the AP pelvic radiographs, patients lied on their back, with the median sagittal plane vertical mesa, both lower limbs straight in a natural position with toes directed forward. Both iliac spines of the patients were kept parallel to the connection with the mesa, and both arms were lifted with the ancon bending near the head. The upper edge of the film was over the crest and the lower edge was over the superior border of pubic symphysis by 10 cm, including ischium. The central beam was directed to the pubic symphysis midpoint.

The lateral radiographs of the hip were carried out in a standard manner with the patients supine and the toe internally rotated 15°. The scope of the radiography included double hip and 400 mm of proximal femur. Digital image acquisition of both groups of patients was achieved by a computer X-ray imaging (computed radiography, CR) system, and video display was saved in the computer in the distributed component object model (DCOM) format.

All cases were implanted with cementless prostheses. A total of 184 cases (56 cases in group A and 62 cases in group B) were treated with the Betacup® acetabulum cup system (LINK, Germany) and 104 cases (44 cases in group A and 38 cases in group B) were treated with the Combicup® acetabulum cup system (LINK, Germany). The adjacent type of acetabular cup diameter increased by 2 mm progressively.

Enterprise-wide PACS Solituons (EBM technologies) software was applied to measure the pelvic height based on the standard AP pelvic radiographs.

The following approach was used for Pelvic height planning (Fig. 1 and Fig. 2): *(15)* the Ranawat triangle delta ABC was plotted according to the method by Ranawat *(21)*, and AC indicated the bevel edge of an isosceles right triangle; *(10)* the horizontal line that connected the bilateral iliac crest and the horizontal line that connected the bilateral ischial tuberosity were drawn, and the vertical distance of the two lines for pelvic was height 'H'; *(24)* the length of the Marker 'L' on the X radiograph was measured; *(23)* the length of the known Marker 'M' was measured; and *(12)* the diameter of acetabulum cup was calculated according to the mathematical formula: $D = \times M \times (H/5) / L$ *(1,25)*.

For conventional templating: the acetabulum prosthesis template (provided by the LINK company) was located under the acetabulum cartilage of the lateral radiographs of the hip, with 45 ° of outreach in a suitable size of acetabulum cup *(9,27)*.

All statistical analyses were performed with SPSS version 20.0 (SPSS, Chicago, IL, USA), using Student's t-test to compare differences in magnification between the two methods. A p value < 0.05 was considered to be statistically significant.

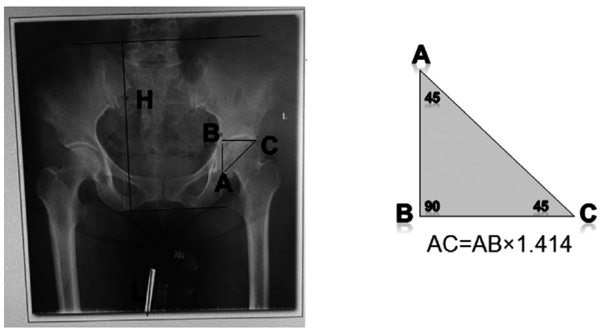

Fig. 1. — Graphical pelvic height measurement and the calculation formula of the hypotenuse isosceles right triangle

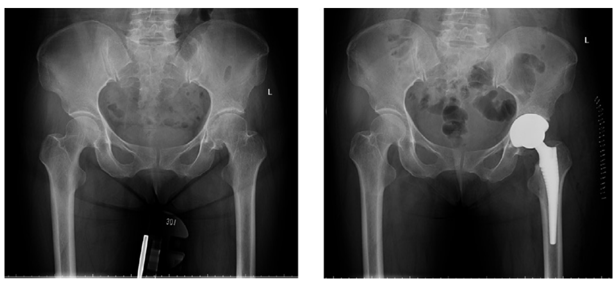

Fig. 2. — The quantitative distribution of varied false types in the two methods

Table II. — Comparison between preoperative measuring of the acetabulum cup size and the intraoperative actual model

Group	Mean (mm)	Standard Deviation (mm)	t	P value
A	2.58	0.89	-6.062	0.000
B	1.38	1.22		

P value <0.05 is considered to be statistically significant.

RESULTS

As shown in Fig 3, compared with the size of acetabular cup actually used during surgery, there were 57 cases (47.5%) with the same size or with one type size discrepancy, 49 (40.8%) with two type size discrepancies, and 14 (11.7%) with three type size discrepancy in group A. By contrast, there were 145 cases (86.3%) with the same size or one type size discrepancy, 20 (11.9%) with two type size discrepancies, and 3 (1.8%) three type size discrepancies in group B. The mean difference between the planned size and actual cup was 2.58 ± 0.89 mm in group A and 1.38 ± 1.22 mm in group B. There was a statistically significant difference between the two methods using the independent samples t-test (P = 0.000, Table 2). The results showed that the goodness of fit of the size of acetabulum cup between the planned size and actual size using the pelvic height planning was clearly higher than that using conventional templating.

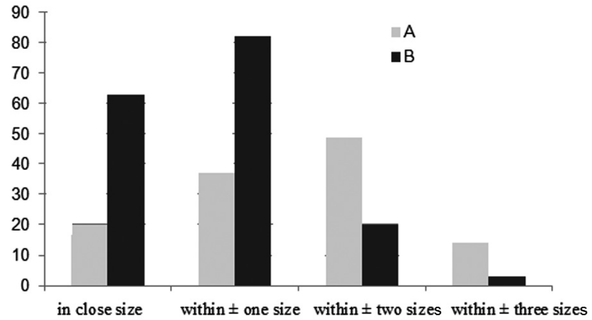

Fig. 3. — A typical case of automatically optimized THA plans. The patient was male, 45 years old, with left hip pain for 1 year in the hospital, diagnosed as avascular necrosis of the left side of the femoral head (Ficat III period). The acetabulum cup diameter with preoperative measuring was 50.4 mm (A). Metal acetabulum cup (50 mm) of bone cement (Betacup), 11 size of femoral bone cement handle (LCU) and delta ceramic head (36 mm) were used intraoperatively (B).

DISCUSSION

This study compared the application value of two methods of preoperative planning of the acetabulum cup: pelvic height planning vs. conventional templating before primary THA. The results demonstrated that the goodness of fit of the size of acetabulum cup between the planned size and actual size using the pelvic height planning was obviously higher than that using conventional templating, indicating that pelvic height planning could be used as a better method for preoperative planning of the acetabulum cup.

The traditional template for preoperative X-ray film measurements to determine the size of the prosthesis is usually with a magnification set at 115% to 120% *(26,30)*. Because of the variation of factors such as the projection distance of the X-ray and the patient's posture in the process of photograph, the magnification of the X-ray is not consistent with the template, which increases the magnification mismatch between the radiograph and the template. Previous studies have shown that the average accuracy of preoperative traditional film template for measuring cementless prostheses is 45% (20-70%) *(5,7,24)*. The traditional film templating method is reliable when X-ray magnification is consistent with the template. The results of the present study showed that the accuracy of the conventional templating method having the same or with one type size discrepancy was 47.5%, and with two type size discrepancies was 40.8% (magnification 113 ± 4.86%). A larger measurement error occurred when there was a greater deviation from the magnification film template.

Pierchon et al. had performed the radiologic evaluation of the rotation centre of the hip, which could be used in preoperative planning *(20)*. Pelvic height planning for measuring the size of acetabulum cup is simple and has strong repeatability, eliminating the interference of inconsistencies between template and pelvic X-ray film magnifications. In this study, the accuracy of the pelvic height planning method, having the same or with one type size discrepancy, could reach up to 86.3%, which was higher than conventional templating. The pelvic height planning method requires standard AP radiographs of the pelvis because the centre deviation affects X-ray films on the crest and the accuracy of the ischial tuberosity connectivity tags and the pelvic height measurement will appear deviated, all of which affect the calculation of the size of the acetabulum cup. We found that the accuracy of the model with two size discrepancies was 11.9% (20 cases), with three size discrepancy was 1.8% (3 cases). When we measured pelvic height on X-ray film before and after operation, we found that the pelvic height values were not consistent, indicating that the variation of the projection centre affected the measurement results of pelvic height planning. The greatest advantage of this method was that it was simple, only requiring standard AP radiographs of the pelvis. Moreover, the data were dependent on real pelvic measurements with a high precision, thus the pelvic height planning method was suitable for application in basic-level hospitals. However, we do not deny that experienced doctors can quickly identify the matching size of acetabulum cup prosthesis for patients. For young and less experienced doctors, especially grass-roots hospital doctors, precise preoperative measurements can effectively help reduce errors and improve surgical success rates.

There were a few limitations of this study. First, all case data and imaging data of the joint surgeries were derived from the People's Liberation Army General Hospital, which may cause bias, and further research is required to provide a definitive conclusion. Second, the method was not framed for patients with pelvic developmental malformation, congenital dysplasia of the hip, or patients undergoing hip revision procedures. These cases need to be combined with other imaging data, such as three-dimensional CT scan and three-dimensional reconstruction for the accurate prediction of the size of the acetabulum prosthesis.

In summary, the present study indicates that the goodness of fit between planned size and actual size of the acetabulum cup using pelvic height planning was clearly higher than using conventional templating, indicating that pelvic height planning is reliable and valid for use in preoperative planning when compared with conventional templating. Further studies and assessments should be conducted to thoroughly evaluate the accuracy of pelvic height planning.

REFERENCES

1. **Abolghasemian M, Samiezadeh S, Jafari D, Bougherara H, Gross AE, Ghazavi MT.** Displacement of the hip center of rotation after arthroplasty of Crowe III and IV dysplasia: a radiological and biomechanical study. *J Arthro* 2013 ; 28 : 1031-1035.
2. **Bertz A, Indrekvam K, Ahmed M, Englund E, Sayed-Noor AS.** Validity and reliability of preoperative templating in total hip arthroplasty using a digital templating system. *Skeletal radiol* 41 : 1245-1249 : 2012.
3. **Bicanic G, Delimar D, Delimar M, Pecina M.** Influence of the acetabular cup position on hip load during arthroplasty in hip dysplasia. *Internat orthop* 2009 ; 33 : 397-402.
4. **Bono JV.** Digital templating in total hip arthroplasty. *J Bone Joint Surg* 2004 ; 86 : 118-122.
5. **Carter LW, Stovall DO, Young TR.** Determination of accuracy of preoperative templating of noncemented femoral prostheses. *J Arthro* 1995 ; 10 : 507-513.
6. **Conn K, Clarke M, Hallett J.** A simple guide to determine the magnification of radiographs and to improve the accuracy of preoperative templating. *J Bone Joint Surg*, British Volume 2002 ; 84 : 269-272.
7. **Della Valle AG, Comba F, Taveras N, Salvati EA.** The utility and precision of analogue and digital preoperative planning for total hip arthroplasty. *Internat Orthop* 2008 ; 32 : 289-294.
8. **Erceg M.** The influence of femoral head shift on hip biomechanics: additional parameters accounted. *Internat Orthop* 2009 ; 33 : 95-100.
9. **Georgiades G, Babis GC, Kourlaba G, Hartofilakidis G.** Effect of cementless acetabular component orientation, position, and containment in total hip arthroplasty for congenital hip disease. *J Arthro* 2010 ; 25 : 1143-1150.
10. **Hojer Karlsen AP, Geisler A, Petersen PL, Mathiesen O, Dahl JB.** Postoperative pain treatment after total hip arthroplasty: a systematic review. *Pain* 2015 ; 156 : 8-30.
11. **Iorio R, Siegel J, Specht LM, Tilzey JF, Hartman A, Healy WL.** A comparison of acetate vs digital templating for preoperative planning of total hip arthroplasty: is digital templating accurate and safe? *J Artho* 2009 ; 24 : 175-179.
12. **Jewett BA, Collis DK.** High complication rate with anterior total hip arthroplasties on a fracture table. *Clin Orthop Rel Res* 2001 ; 469 : 503-507.
13. **Kosashvili Y, Shasha N, Olschewski E** *et al.* Digital versus conventional templating techniques in preoperative planning for total hip arthroplasty. *Canad J Surg* 2009 ; 52 : 6-11.
14. **Kosashvili Y, Shasha N, Olschewski E** *et al.* Digital versus conventional templating techniques in preoperative planning for total hip arthroplasty. *Canad J Surg* 2009 ; 52 : 6.

15. **Learmonth ID, Young C, Rorabeck C.** The operation of the century: total hip replacement. *Lancet* 2007 ; 370 : 1508-1519.
16. **Maloney WJ, Keeney JA.** Leg length discrepancy after total hip arthroplasty. *J Arthro* 2004 ; 19 : 108-110.
17. **Miashiro EH, Fujiki EN, Yamaguchi EN** *et al.* Preoperative planning of primary total hip arthroplasty using conventional radiographs. *Rev Brasil Ortop* 2014 ; 49 : 140-148.
18. **Oddy M, Jones M, Pendegrass C, Pilling J and Wimhurst J.** Assessment of reproducibility and accuracy in templating hybrid total hip arthroplasty using digital radiographs. *J Bone Joint Surg*, British Volume 2006 ; 88 : 581-585.
19. **Petretta R, Strelzow J, Ohly NE, Misur P, Masri BA.** Acetate Templating on Digital Images Is More Accurate Than Computer-based Templating for Total Hip Arthroplasty. *Clin Orthop Rela Res* 2015 ; 1-8.
20. **Pierchon F, Migaud H, Duquennoy A, Fontaine C.** [Radiologic evaluation of the rotation center of the hip]. *Revue de chirurgie orthopedique et reparatrice de l'appareil moteur* 1993 ; 79 : 281-284.
21. **Ranawat CS, Dorr LD, Inglis AE.** Total hip arthroplasty in protrusio acetabuli of rheumatoid arthritis. *J Bone Joint Surg* 1980 ; 62 : 1059-1065.
22. **Riddick A, Smith A, Thomas DP.** Accuracy of preoperative templating in total hip arthroplasty. *J Orthop Surg* 2014 ; 22.
23. **Sariali E, Leonard P, Mamoudy P.** Dislocation after total hip arthroplasty using Hueter anterior approach. *J Arthro* 2008 ; 23 : 266-272.
24. **Sariali E, Mauprivez R, Khiami F, Pascal-Mousselard H, Catonne Y.** Accuracy of the preoperative planning for cementless total hip arthroplasty. A randomised comparison between three-dimensional computerised planning and conventional templating. *Orthop Trauma: Surg Res* 2012 ; 98 : 151-158.
25. **Sariali E, Mouttet A, Pasquier G, Durante E, Catone Y.** Accuracy of reconstruction of the hip using computerised three-dimensional pre-operative planning and a cementless modular neck. *J Bone Joint Surg*, British Volume 2009 ; 91 : 333-340.
26. **Sköldenberg OG, Bodén HS, Salemyr MO, Ahl TE, Adolphson PY.** Periprosthetic proximal bone loss after uncemented hip arthroplasty is related to stem size: DXA measurements in 138 patients followed for 2-7 years. *Acta orthop* 2006 ; 77 : 386-392.
27. **Stans AA, Pagnano MW, Shaughnessy WJ, Hanssen AD.** Results of total hip arthroplasty for Crowe Type III developmental hip dysplasia. *Clin Orthop Rel Res* 1998 ; 348 : 149-157.
28. **Valle AGD, Comba F, Taveras N, Salvati EA.** The utility and precision of analogue and digital preoperative planning for total hip arthroplasty. *Internat Orthop* 2008 ; 32 : 289-294.
29. **Valle AG, Piccaluga F, Salvati EA.** The precision and usefulness of preoperative planning for cemented and hybrid primary total hip arthroplasty. *J Arthro* 2005 ; 20 : 51-58.
30. **White S, Shardlow D.** Effect of introduction of digital radiographic techniques on pre-operative templating in orthopaedic practice. *Annals of The Royal College of Surgeons of England* 2005 ; 87 : 53.