Original Article

pISSN: 2287-3260 / eISSN: 2287-3279
Hip Pelvis 2024;36(2):129-134
https://doi.org/10.5371/hp.2024.36.2.129

Hip & Pelvis

Surgeon's Experience and Accuracy of Preoperative Digital Templating in Primary Total Hip Arthroplasty

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Purpose: Preoperative planning has become essential in performance of total hip arthroplasty (THA). However, data regarding the effect of the planner's experience on the accuracy of digital preoperative planning is limited. The objective of this study was to assess the accuracy of digital templating in THA based on the surgeon's experience.

Materials and Methods: A retrospective study was conducted. An analysis of 98 anteroposterior pelvic radiographs, which were individually templated by four surgeons (two hip surgeons and two orthopaedic residents) using TraumaCad® digital planning, was performed. A comparison of preoperatively planned sizes with implanted sizes was performed to evaluate the accuracy of predicting component size. The results of preoperative planning performed by hip surgeons and orthopaedic residents were compared for testing of the planner's experience.

Results: Femoral stem was precisely predicted in 32.4% of cases, acetabular component in 40.3%, and femoral offset in 76.7%. Prediction of cup size showed greater accuracy than femoral size among all observers. No differences in any variable were observed among the four groups (acetabular cup P=0.07, femoral stem P=0.82, femoral offset P=0.06). All measurements showed good reliability (intraclass correlation coefficient [ICC] acetabular cup: 0.76, ICC femoral stem: 0.79).

Conclusion: The results of this study might suggest that even though a surgeon's experience supports improved precision during the planning stage, it should not be restricted only to surgeons with a high level of experience. We consider preoperative planning an essential part of the surgery, which should be included in training for orthopaedics residents.

Keywords: Hip, Total hip arthroplasty, Preoperative care, Data accuracy, Dimensional measurement accuracy

INTRODUCTION

Total hip arthroplasty (THA) is a commonly performed and effective procedure in the field of orthopaedics[1]. The primary objective of THA is to relieve pain, restore biomechanics, and improve hip function[2]. To ensure favorable outcomes, preoperative planning has become an essential part of the procedure[1,3]. Improved accuracy of implant size selection, identification of patients who may require non-standard implants, achievement of leg-length equalization, and anticipating potential intraoperative problems has been demonstrated with use of preoperative templating[3-5]. Preoperative templating also involves development of a plan that can enable the surgical team to ensure that the theatre is adequately stocked with the relevant prosthesis sizes and suitable alternatives, and at the same time, can reduce the inventory of implants in the operating room[6].

Preoperative and intraoperative planning was initially performed using acetate radiographs and transparent magnified plastic templates[3]. Previous studies have reported that these methods showed acceptable

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Received: August 8, 2023 **Revised:** December 18, 2023 **Accepted:** December 22, 2023

accuracy and effectiveness[7-9]. Advances in technology have led to the introduction of PACS (Picture Archive and Communications Systems) in most hospitals, leading to a progressive elimination of acetate radiographs. Reproducibility and accuracy in predicting implant sizes have been reported with use of digital templating[9-11]. A systematic review reported on the high level of accuracy of digital two-dimensional templating in prediction of prosthesis hip size (>70% for within one prosthesis size) for both cemented and uncemented THA implants, supporting its continued routine use in preoperative planning, regardless of the method of fixation[3]. In addition, digital preoperative THA does not require image printing and enables maintenance of a permanent and easily accessible digital record and is therefore a more cost-effective method[10].

Despite the benefits of preoperative templating, inaccurate templating may result in intraoperative complications including femoral fractures, instability, insufficient offset, or leg length discrepancy[3,6]. Considering the benefits and risks of inaccurate preoperative templating, there is no consensus in the literature with regard to whether digital templating should be performed only by experienced hip surgeons or by orthopaedic residents as well[10-12]. The objective of this study was to examine the effect of surgical experience on accuracy of digital templating in THA. We hypothesize that less experienced surgeons would be able to perform accurate templating with adequate training.

MATERIALS AND METHODS

1. Study Design

Approval was obtained from the Institutional Review Board (IRB) of Fundació Assistencial Mútua Terrassa (P/22-004) for conduct of a retrospective review of patients who underwent THA from October 2018 to March 2019 at Fundació Assistencial Mútua Terrassa. The written informed consent was waived by the IRB due to the retrospective nature of the study. Patients were identified through our prospectively collected institutional registry.

The inclusion criteria for the patient's analysis were: (1) patients aged older than 50 years; (2) patients who underwent THA for treatment of primary osteoarthritis of the hip; and (3) patients who underwent THA and had received implanted primary ordinary hip prosthetic components. The following patients were excluded: (1) THA patients who underwent hip resurfacing surgery; (2) THA patients who had undergone previous surgery on the operated hip and had received hip implants such as osteosynthesis nail, plates, or screws; (3) patients who underwent THA for treatment of a hip fracture, hip dysplasia, or osteoarthritis of the hip for rheumatoid, polio, or hemophilia; and (4) patients with incomplete medical records, including inappropriate preoperative X-ray images, in the electronic clinical history.

2. Study Intervention

1) Preoperative planning

Advance preoperative planning was performed in a blinded manner to ensure that all participants had no knowledge regarding the details of the planning process.

Measurements were performed on the preoperatively calibrated anteroposterior (AP) pelvis X-ray (Fig. 1). To ensure consistency and quality, the same technical team, previously trained to minimize heterogeneity, was employed for the acquisition of all radiographs. A pelvis X-ray with anatomical landmarks described in the Blumetritt biomechanical model was considered appropriate[13]. Templating was performed in all cases using TraumaCad® digital planning software (BrainLab Ltd.). Magnification was adjusted using a belt with a 25-mm diameter radio-opaque ball as a calibration marker provided by TraumaCad®.

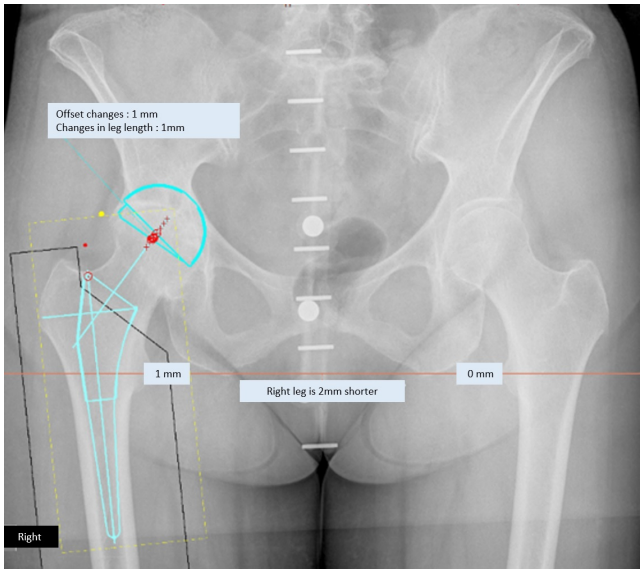

Fig. 1. Calibrated anteroposterior pelvis X-ray.

2) THA surgery

We attempted to include surgeons who shared a common surgical methodology; thus, all surgical procedures were performed by three surgeons from the hip unit who performed operations together in all cases using a posterior approach to the hip joint. The same THA system was used in all cases: G7® cementless acetabular cup (Zimmer-Biomet) and Taperloc® cemented or cementless hip stem (Zimmer-Biomet).

The surgical procedures adhered to preoperative templating performed by proficient hip surgeons. A comprehensive individual analysis of all cases was subsequently performed by four observers: two hip surgeons (HS) with 16 and three years of experience, and two orthopaedic residents (OR) in their first (1st) and fourth (4th) years. The observers were blinded to the definitive implanted components and had no knowledge of each other's findings.

3. Statistical Analysis

The IBM SPSS Statistics software (ver. 22; IBM Corp.) and RStudio software (RStudio 1.3) were used for assessment of the observer's templating accuracy and interobserver variability and reliability.

Two types of data sets were differentiated: discrete numerical variables (acetabular cup and femoral stem) and categorical variables (femoral offset). Assessment of the percentage of matching, both absolute and an interval ±1 and ±2, was performed. Kappa correlation coefficient was used to assess the degree of correlation between the implanted components and planned implant sizes (acetabular cup and femoral stem). A 0 result indicated no matching, while a ±1 result indicated perfect matching (>0.9: excellent matching, 0.8-0.89: good matching, 0.7-0.79: acceptable matching, <0.7: poor matching). The kappa index was used for evaluation of the femoral offset due to its categorical nature. Again, a 0 result indicated no pairing while +1 result indicated perfect pairing (>0.81: excellent matching, 0.61-0.8: good matching, 0.41-0.6: acceptable matching).

A correlation matrix was used for evaluation of interobserver variability, whereas the intraclass correlation coefficient (ICC) was assessed for evaluation of interobserver reliability. Regarding statistical significance, P-value was obtained using the Kruskal–Wallis test for the cup and femoral stem, and the χ^2-test for determination of femoral offset. The level of statistical significance of the variables was established at $P \leq 0.05$.

RESULTS

Ninety-seven patients were finally included in the study, representing 98 AP radiographs of the hip. Templating was performed retrospectively by the four surgeons for each case; 392 observations were obtained. The study included 60 males (61.9%). The mean age of patients was 66.7±3.2 years. Cementless stems were used in 60 out of 98 cases (61.2%).

1. Acetabular Cup

The correct acetabular cup size was predicted in 40.3% of cases (48% senior HS, 43% junior HS, 32% 4th year OR, 39% 1st year OR). If the implant size is accepted as correct within an interval of one size above or below, accuracy increases to 85%; and when considering an interval size up to ±2, accuracy increases to 98% (Table 1). Regarding the degree of correlation, the senior and junior HS obtained good matching (0.82 and 0.81, respectively). The 4th year and 1st year ORs obtained acceptable matching (0.73 and 0.78) (Table 2).

Table 1. Accuracy of Cup, Femoral Stem, and Femoral Offset

	Senior HS	Junior HS	4th OR	1st OR
Cup accuracy (%)				
Exact match	48	43	32	39
±1	86	88	83	85
±2	98	98	99	98
Femoral stem accuracy (%)				
Exact match	40	46	13	30
±1	61	64	29	46
±2	66	67	45	53
Femoral offset accuracy (%)				
Exact match	85	81	71	70
±1	-	-	-	-
±2	-	-	-	-

HS: hip surgeon, OR: orthopaedic surgeon.

Table 2. Degree of Correlation

	Senior HS	Junior HS	4th OR	1st OR
Acetabular cup	0.82	0.81	0.73	0.78
Femoral stem	0.75	0.85	0.69	0.69
Femoral offset	0.87	0.81	0.74	0.71

HS: hip surgeon, OR: orthopaedic surgeon.

2. Femoral Stem

The femoral stem size was accurately predicted in 32.4% of cases (40% senior HS, 46% junior HS, 13% 4th year OR, 30% 1st year OR). An interval of ±1 resulted in an accuracy of 50%, and an interval of ±2 resulted in an accuracy of 58% (Table 1). Acceptable matching was obtained in the senior HS group (0.75) while good matching (0.85) was obtained in the junior HS group. The results from both resident groups indicated poor matching (0.69) (Table 2).

3. Femoral Offset

According to kappa coefficient, the femoral offset was precisely predicted in 76.7% of cases (85% senior HS, 81% junior HS, 71% 4th year OR, 70% 1st year OR) (Table 1). Regarding the degree of correlation, excellent matching was obtained by the senior HS (0.87) and the junior HS (0.81), and good matching was obtained for the 4th year OR (0.74) and the 1st year OR (0.71), respectively (Table 2).

4. Interobserver Variability and Reliability

A summary of the results for interobserver variability is provided in Table 3. Less than 20% of disagreement was observed between HS in all measurements. For OR, higher discrepancy was observed for acetabular cup (up to 30%) compared to femoral stem (less than 15%). The results showed good agreement between HS and OR (variability less than 30% in all measurements). Greater variability was observed for acetabular cup compared with femoral stem or offset.

Table 3. Interobserver Variability

	Senior HS	Junior HS	4th OR	1st OR
Cup				
Senior HS	1.00	0.82	0.74	0.78
Junior HS	0.82	1.00	0.76	0.78
4th OR	0.74	0.76	1.00	0.67
1st OR	0.78	0.78	0.67	1.00
Stem				
Senior HS	1.00	0.82	0.83	0.82
Junior HS	0.82	1.00	0.72	0.74
4th OR	0.83	0.72	1.00	0.85
1st OR	0.82	0.74	0.85	1.00
Offset				
Senior HS	1.00	0.82	0.74	0.78
Junior HS	0.82	1.00	0.76	0.78
4th OR	0.74	0.76	1.00	0.67
1st OR	0.78	0.78	0.67	1.00

HS: hip surgeon, OR: orthopaedic surgeon.

In analysis of differences in *P*-value among the four groups, no statistically significant differences were observed for any variable (acetabular cup: P=0.07, femoral stem: P=0.82, femoral offset: P=0.06). Regarding reliability, as measured using the ICC, the results showed good reliability for all measures (ICC acetabular cup: 0.76, ICC femoral stem: 0.79).

DISCUSSION

Preoperative templating for performance of THA has led to increased rates of success as it can enable identification of patients who may require non-standard implants, improve anatomy restoration, and allow for anticipation of any potential complications that might arise during surgery[3,5,11]. However, surgeons should also rely on their intraoperative assessment and should not become rigid in adhering to their preoperative templates. Many studies have demonstrated that accurate prediction can be achieved using both analogical and digital templating[14]. The main findings of our study were that even though surgeon's experience supports r improved precision during the planning stage, it should not be restricted only to surgeons with a higher level of experience. Femoral stem, acetabular component sizes, and femoral offset were precisely predicted in 32.4%, 40.3%, and 76.7%, respectively. All measurements showed good reliability.

Despite femoral stem, acetabular component sizes, and femoral offset were precisely predicted in 32.4%, 40.3%, and 76.7%, respectively; when evaluating the prosthesis size (±1), the accuracy increased to 50% for the femoral stem and 85% for the acetabular cup size. These results are similar to those reported in other publications; in a systematic review, accuracy within one prosthesis size (±1) was 0.89 for cemented stems (95% confidence interval [CI] 0.83-0.95), 0.78 for cemented cups (95% CI 0.67-0.89), 0.74 for uncemented stems (95% CI 0.66-0.82), and 0.73 for uncemented cups (95% CI 0.67-0.79) (test of group differences: P=0.010)[3]. According to kappa coefficient, femoral offset was precisely predicted in 76.7% of cases. The degree of correlation was excellent according to the senior HS (0.87) and the junior HS (0.81) and good for the 4th year OR and the 1st year OR (0.74 and 0.71, respectively). Other studies reported similar results; Kearney et al.[15] accurately predicted the femoral offset in 91% of cases (88% consultant, 93% registrar). In addition, Shin et al.[16] reported that the intra- and interob-

server reliability for difference in femoral offset using the ICC ranged from 0.90 (95% CI 0.88-0.93) to 0.96 (95% CI 0.96-0.97). According to the literature and based on our results, femoral offset is the most reliable size for prediction in templating hips for both levels of surgeon.

Data regarding the effect of the planner's experience on the accuracy of digital preoperative planning are limited. There is no consensus in the literature regarding whether surgical experience may or may not be critical for performance of THA digital templating. Based on our results, all measurements showed good reliability. Hsu et al.[17] performed retrospective templating on 49 THA procedures performed by personnel with varying levels of orthopaedic training; excellent accuracy and reproducibility were obtained in all groups. Kumar et al.[18] also reported good interobserver reliability for 45 cases of primary uncemented THA. By contrast, Mittag et al.[19] reported that statistically significant differences were observed between the surgically experienced and inexperienced groups in more than 106 cases. In a study by Montiel et al.[10], although their findings showed good interobserver reliability, stronger agreements were obtained between surgeons with a higher level of surgical experience. Holzer et al.[20] reported that higher levels of experience resulted in a statistically significant higher percentage of adequate preoperative planning for femoral components, but not for acetabular components. Similarly, Jung et al.[21] reported that a lower level of experience had no effect on the planning results for acetabular components; however, considerable and significant differences were observed in planning the femoral components. It should be noted that cementation might bias results regarding the accuracy of preoperative planning[20,21]. Due to the different cement mantle around the stem, our results suggest the accuracy of digital templating using TraumaCad® regardless of surgeon's level of experience. However, better results were obtained between surgeons with a higher level of surgical experience. As stated by Montiel et al.[10], we also consider that the precision of planning can be influenced by experience in the management of digital software. This would explain why surgeons with greater experience in digital planning may obtain more accurate results than others with a higher level of surgical experience. In our study, better results were obtained from the 1st year OR compared with the 4th year OR. This result could be explained by the fact that the 1st year OR has used digital software since the beginning of his orthopaedic training. These results suggest that preoperative planning should not be restricted only to surgeons with a higher level of experience, and therefore may have clinical relevance. We consider preoperative planning an essential part of the surgery, which should be included in training for orthopaedics residents.

This study has limitations in that all data analyses were performed retrospectively. In addition, femoral stems were either cemented or uncemented, which might affect the accuracy of planning. The small number of examiners in each group and the small sample size may be an additional limitation. Three-dimensional (3D) planning using CT images is an important emerging field[22]. Excellent reliability for component size and alignment has been reported with use of 3D, regardless of surgeon's experience. In addition, previous studies have reported more favorable results when compared with traditional templating[23,24]. However, its high cost and associated radiation can cause surgeons to reconsider the need for planning in all cases, leaving 3D planning for use in exceptional situations.

CONCLUSION

The results of this study might suggest that even though surgeon's experience supports improved precision during the planning stage, it should not be restricted only to surgeons with a higher level of experience. Preoperative planning is an essential part of the surgery, and orthopaedic residents should be participants, and should be included in training for residents.

Funding

No funding to declare.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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