The Accuracy of Preoperative Templating in Total Knee Arthroplasty

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Objective: *Radiographic templates have been developed to assist with the preoperative planning process. However, the clinical usefulness of preoperative templating in total knee replacement is still lacking. The present study aims to evaluate the accuracy of preoperative templating in primary total knee replacement.*
Material and Method: *A retrospective study of 98 patients and 113 knees was carried out. Both the anteroposterior and lateral radiographic views were templated using the templates for DePuy Sigma PFC, fixed bearing total knee system and the template size was documented for each patient pre-operatively. The operative records were then reviewed to determine the size of the implant used during the operation.*
Results: *The overall accuracy between the preoperative template size and the final implant size was 50.4% for the femoral component and 55.8% for the tibial component. The highest prediction for tibial assessment was the anteroposterior view and the lateral intercondylar view for femoral assessment.*
Conclusion: *Approximately 50% of the patients had a preoperative template size that matched the actual implant used. Many factors influence the final choice of the prosthesis used during total knee replacement; therefore, the preoperative template size can only be used as a rough guide.*

Keywords: *Preoperative template, Size, Total knee replacement, Accuracy, Clinical usefulness, Radiographic view*

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Preoperative templating is considered an important part of preparation for total joint replacement. Generally, meticulous preoperative planning allows the surgeon to perform the procedure precisely, avoid potential intraoperative complication, and achieve good surgical results(1-3). It is well accepted that preoperative templating is of paramount importance in obtaining reproducible results in total hip replacement regarding restoration of hip biomechanics and limb length equality(4-7). However, this step of preoperative planning is not well emphasized in total knee replacements. Moreover, only few studies have evaluated the clinical usefulness and predictability of preoperative templating techniques in total knee replacements(8,9). Therefore, the present study aimed to evaluate the accuracy and reliability of preoperative templating in total knee replacements.

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Material and Method

A retrospective review of the preoperative radiographs, templates, plans and operative reports of consecutive primary total knee replacements was performed. All patients underwent surgery between January 2002 and January 2004 by a single surgeon (AmU). The preoperative diagnosis was end-stage primary osteoarthritis in every patient, except for one patient with secondary osteoarthritis due to gouty arthritis. The exclusion criteria were patients who required a complex surgical procedure such as extensive bone grafting and osteotomy in which the anatomy could not be easily discerned, those with poor quality radiographs, and those with one or more missing radiographs. This left 113 knees in 98 patients for the present study. There were nine men and 89 women with an average age of 68.7 years (range 46-87 years old). The mean deformity was varus 8 degrees (range, 20° varus to 2° valgus), and the average range of motion was 118 degrees of flexion with flexion contacture in 40 knees (range, 20° flexion contracture to 10° of hyperextension).

The surgeon used the cemented, Sigma PFC, fixed bearing knee system in all patients (DePuy, Warsaw, IN). Both preoperative and postoperative radiographs consisted of an anteroposterior (AP) and lateral view of the knee. These radiographs were obtained with a standard 100 cms distance from the tube to X-ray plate, which results in an average magnification of 20 $\pm$ 6%[10,11]. No magnification marker was used. The templating was performed by single author (AaU.) who had no prior knowledge of the implants used in each patient. Four measurements were taken: femoral anteroposterior and lateral view, tibial anteroposterior and lateral view[3]. The measurement of femoral lateral view was subdivided into three methods. All these measurements were compared with the actual femoral and tibial components used, which were collected from the operative records.

For the anteroposterior view of the femur, the templating began by drawing a line that represented as a mechanical axis. The predicted femoral component should be perpendicular to this line and covered both the medial and lateral condyles as much as possible, taking care not to overhang on each side. For the lateral view, the template should be placed to maximize coverage of the distal femoral bone. With the anterior flange of the femoral component being flush with the anterior femoral cortex, the center of the prosthesis pointed along the longitudinal axis of the femoral shaft, avoiding flexion or extension of the femoral component. The authors subdivided the measurement on this femoral lateral view by using different landmarks on the posterior femoral cortex. The authors used the small condyle that represents the lateral femoral condyle, the large condyle that represents the medial femoral condyle, and the intercondylar line that represents an area between the medial and lateral femoral condyle.

For the anteroposterior view of the tibia, the authors placed the template on the tibial plateau with the tibial stem parallel to the mechanical axis. The largest size, which covered the greatest amount of host bone without overhang on each side, was selected. For the lateral view, the template was placed with the tibial stem parallel to the anterior tibial cortex and adjusted so that the posterior slope best matched the patient's own anatomy.

The preoperative radiographic template size and the final prosthesis size were recorded for each patient. The accuracy of the preoperative templating technique on each view was reported as a percentage and shown on a 95% Confidence Interval (95% CI). The Kappa Coefficient was used to provide the degree of agreement between the preoperative template values and the actual components used[12].

Results

For the femoral component size, the templated size measuring from radiographic lateral intercondylar view had the highest accuracy of 50.4% (57/113 knees) as shown in Table 1. This accuracy increased to over 90% (94.7% for lateral intercondylar view and 97.3% for anteroposterior view) of templated sizes within one size above or below those actually used (Table 2). For the tibial components, the highest prediction of the final component size was measured from tibia AP view with the accuracy of 55.8% (Table 1), however, 96-97% were within 1 size larger or smaller as shown in Table 2.

Table 1. The accuracy of preoperative templating for femoral and tibial components

Radiographic view	Exactly matched (%)	95% CI
Femoral AP assessment	38.1	29.6-47.3
Lateral assessment		
Small femoral condyle	20.4	14.1-28.9
Intercondylar area	50.4	41.4-59.5
Large femoral condyle	12.4	7.5-19.7
Tibial AP assessment	55.8	46.6-64.6
Tibial lateral assessment	46.9	38.0-56.1

Table 2. The accuracy of preoperative templating within 1 size (smaller or larger) for the femoral and tibial components

Radiographic view	% matched within 1 size	95% CI
Femoral AP assessment	97.3	92.5-99.1
Lateral assessment		
Small femoral condyle	79.6	71.3-86.0
Intercondylar area	94.7	88.9-97.5
Large femoral condyle	50.4	41.4-59.5
Tibial AP assessment	96.5	91.3-98.6
Tibial lateral assessment	97.3	92.5-99.1

By using the Kappa Coefficient to indicate the degree of agreement[13], the lateral intercondylar view of femur and AP view of the tibia gave the best agreement for the femoral component (0.44) and tibial component (0.46) respectively. Both values indicate moderate levels of agreement above chance.

Discussion

Preoperative templating has been advocated as a part of preoperative planning in total knee surgery. The manufacturers provide various sets of templates for multiple prosthetic designs. The aims of templating are to reconstruct the biomechanics of the knee joint, predict the size of the optimal prosthetic component size, and preemptively evaluate for any problem that the surgeon may encounter during the surgery. The principle of templating is to select the component that provides maximum bony containment and least removal of the host bone while maintaining the correct mechanical alignment[1,3]. It has been widely accepted that inappropriate size of the prosthesis can be a potential cause of postoperative problem and unfavorable outcome[14-17]. Undersizing of the components may lead to iatrogenic fracture during the operation or postoperative instability due to imbalance of the flexion and extension gap, whereas, oversizing of the femoral components may lead to decreased postoperative flexion, patellofemoral maltracking, increased patellofemoral forces and shear, and possibly pain compromising the end result[18-26].

Aslam et al reported the reliability of preoperative templating in 25 primary total knee arthroplasties. They found that the exact size of the prosthesis was predicted for 49% of the femoral component and 67% of the tibial component[8]. Heal and Blewitt studied the Kinemax total knee arthroplasty templates and found only 57% accuracy with the preoperative templates[9]. Similar to these earlier reports, the authors found the overall accuracy of 50.4% for the femoral component and 55.8% for the tibial component with moderate agreement between preoperative templates and the actual component used.

This low accuracy can be explained by several possibilities. Firstly, the rotation of the preoperative radiographs can obscure some important anatomic landmarks and distort the actual bony configuration. This could lead to an error in measurement of the prosthetic component size. Although the authors tried to exclude rotated radiographs, it was not always possible to have the perfectly aligned radiographs available for surgery. Secondly, the patient's preoperative deformity such as flexion contracture or rotational deformity has been identified as a possible source of error in preoperative templating. Heal and Blewitt found that with the degree of knee flexion contracture increased, the distance between the knee and x-ray plate increased as well. This resulted in a greater degree of magnification on the radiographs[9]. Moreover, the rotational deformity of the knee can cause an error in sizing of both the femoral and tibial component in AP and lateral views as mentioned earlier.

Finally, the surgical technique has been shown to affect the final implant size. Because the femoral component size has an influence on the flexion gap, the surgical technique, which is based on balancing the gap may lead to smaller sizes of the femoral component than we anticipated based on anatomical sizing alone. An example of this situation is clearly seen in a recurvatum knee. After the standard distal femoral cut, a large extension space may result. In this situation, the surgeon may intentionally downsize the femoral component in order to balance the relatively tight flexion gap. The present study tried to minimize this factor by using the cases from only one surgeon in order to reduce the influence of various surgical techniques.

The authors found that the lateral intercondylar view had the highest prediction of the final femoral component used. To measure the distal femur, the femoral sizing guide (anterior reference) was used in all cases. This femoral sizing guide measured the distal femur only in 1 dimension (antero-posterior dimension (A/P)). Therefore, the size from lateral view of the radiograph mainly determined the overall size of the femoral component. With this method, the femoral component may be fit only on the A/P dimension but overhang the bone at medial-lateral (M/L) interfaces. In this situation, the surgeon may make an intraoperative adjustment by increasing or decreasing the femoral component size depending on the balance of the flexion and extension gap and to compensate for the overhang. On the other hand, the authors used the medial-lateral dimension of the tibia to consider the appropriate intraoperative size because it was hard to visualize the posterior tibial cortex. Therefore, the tibial AP view had the highest prediction for the final implant used.

Although, it is possible that the prosthetic components utilized in the surgery will not be the best fit for the patient's own anatomy and leads to postoperative problems, the authors are not aware of any obvious overhanging or usage of undersized components from the postoperative radiographs. In addition, there were no intraoperative complications such as fracture or mid-flexion instability. Recently, some manufacturers have addressed the anatomical differences between male and female, and introduced a new implant design, which the femoral component narrower in M/L dimension when compared to the traditional component of the same A/P dimension, to allow better fit with the patient's bone and fewer intraoperative adjustments[(27-29)]. Because these new implant designs are not available all the time, careful preoperative templating may help the surgeon to have the appropriate sized implants brought to the operative room.

The prediction of femoral and tibial component size within $\pm$ 1 size was achieved in 97.3% and 96.5% of the femoral and tibial component respectively. With this high accuracy, it should theoretically reduce the surgical time by allowing the nurse and surgical team to have the implants available in the operative room. Della Valle et al showed that the time delay of bringing each of the two components in total hip arthroplasty from the implant room to the operating room is approximately 2 minutes. By having both components available in the operating room, this could save about 400 minutes of operating room time for any 100 surgeries at one of the author's institutions[(30)].

The major drawback of the present study is its retrospective design and lack of the exact magnification of the preoperative radiographs. It is well known that magnification is directly proportional to the distance between the knee and film; therefore, increased magnification can be expected in obese patients and conversely, less magnification in thin patients. Although a properly placed magnification marker may result in additional accuracy in templating, it is the authors' experience that consistent use of a magnification marker was not easily instituted in a high volume multispecialty university setting such as the authors'. Nevertheless, the authors recognize that the use of magnification markers could potentially improve accuracy in templating, and reappraisal of the radiographic assessment, including the use of digital radiography with known magnification may improve these results[(31)].

In conclusion, the highest prediction of the final component size was achieved by preoperative templating on the lateral view of the femur and anteroposterior view of the tibia with the accuracy of 50.4% and 55.8% respectively. However, this prediction can be improved to more than 90% accuracy by having 1 size smaller or larger available in the operative room. Preoperative templating may optimize surgical time and facilitate the identification of specific cases that require special implants.

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การศึกษาความแม่นยำของการวัดขนาดข้อเข่าเทียมจากภาพถ่ายรังสีก่อนการผ่าตัด

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วัตถุประสงค์: *ในการผ่าตัดเปลี่ยนข้อเทียมนั้นศัลยแพทย์มักจะต้องวัดขนาดของข้อเทียมจากภาพถ่ายรังสีเพื่อใช้เป็นขนาดอ้างอิงระหว่างผ่าตัดแต่เนื่องจากกการศึกษาถึงความถูกต้องแม่นยำของการวัดขนาดข้อเข่าเทียมยังมีไม่มากนัก ดังนั้นการศึกษาครั้งนี้จึงมีวัตถุประสงค์เพื่อที่จะหาความถูกต้องแม่นยำของการวัดขนาดข้อเข่าเทียมจากภาพถ่ายรังสีก่อนการผ่าตัด*

วัสดุและวิธีการ: *ผู้ศึกษาได้รวบรวมภาพถ่ายรังสีของข้อเข่าเทียมก่อนการผ่าตัด ในผู้ป่วยจำนวน 98 ราย (113 เข่า) ภาพถ่ายรังสีประกอบด้วยภาพถ่ายรังสีในแนวตรง และแนวข้างของข้อเข่าทำมุมตั้งฉากซึ่งกันและกัน ผู้ศึกษาได้ทำการวัดและประเมินขนาดของข้อเข่าเทียมที่น่าจะเหมาะสมกับผู้ป่วยรายนั้น ๆ โดยใช้ภาพจำลอง ข้อเข่าเทียมขนาดต่าง ๆ ซึ่งได้ทำมาเพื่อให้เหมาะสมกับขนาดขยายของข้อเข่าผู้ป่วยในภาพถ่ายรังสีนั้น ๆ ขนาดที่วัดได้ทั้งจากภาพรังสีในแนวตรงและแนวข้างได้ถูกบันทึกไว้ และนำมาเปรียบเทียบกับขนาดที่ใช้จริงระหว่างการผ่าตัด*

ผลการศึกษา: *จากภาพถ่ายรังสีของข้อเข่าเทียมจำนวน 113เข่า ความถูกต้องแม่นยำโดยรวม มีค่าประมาณ 50.4% สำหรับข้อเข่าเทียมส่วน femur และ 55.8% สำหรับข้อเข่าเทียม ส่วน tibia โดยผู้ศึกษาพบว่าภาพถ่ายรังสีแนวตรงมีความถูกต้องแม่นยำมากที่สุดในการคาดคะเนขนาดของข้อเข่าเทียมส่วน tibia และภาพถ่ายรังสีแนวข้างมีความถูกต้องแม่นยำมากที่สุดในการคาดคะเนขนาดของข้อเข่าเทียมส่วน femur*

สรุป: *เนื่องจากมีหลายปัจจัยที่มีผลต่อศัลยแพทย์ในการเลือกขนาดของข้อเข่าเทียมระหว่างผ่าตัดสำหรับผู้ป่วยแต่ละราย ดั้งนั้นการวัดขนาดของข้อเข่าเทียมก่อนการผ่าตัดจากภาพถ่ายรังสีจึงเป็นแค่การคาดคะเนขนาดของข้อเข่าเทียมที่จะใช้จริงอย่างคร่าว ๆ เท่านั้นโดยมีค่าความแม่นยำประมาณ 50%*