Accuracy of Knee Implants Sizing Predicted by Digital Images

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Background: *Accurate preoperative templating to predict implant size and position can facilitate precise, efficient, and reproducible knee replacement operations. Preoperative templating for total knee arthroplasty can be performed with digital images of the knee implants on digital radiographs of the knee.*
Objective: *To determine the accuracy of knee implants sizing predicted by digital images.*
Material and method: *A retrospective study was done to assess the accuracy of the knee implant sizing predicted by digital images in 100 Thai adults, who had osteoarthritis of the knee. Digital anteroposterior and lateral radiographs of the knee were used in measuring the level of distal femoral resection and the level of proximal tibial resection. Anteroposterior and mediolateral diameter of femur and tibia were determined and the implant size was choosen. The results from digital images were compared with the size of actual femoral and tibial implants used at the time of surgery. All variables were analyzed. The correlation coefficients were calculated to determine interobserver and intraobserver reliability.*
Results: *The accuracy of digital preoperative plans for femoral component was 53.1%. The accuracy of digital preoperative plans for tibial component was 59.3%. The digital preoperative planning predicted 79 of 81 (97.6%) femoral implants to within one size and predicted 77 of 81 (95.1%) measurements of the tibial implants to within one size.*
Conclusion: *Digital images can help to focus the thoughts and plans of the operation. When planning is performed, it can identify extremes of sizes that may require special order, and planning can predict size mismatches between femoral and tibial implants. When recognized ahead of time, these limitations can be accommodated during the surgical procedure or a different implant system chosen. Predicting implant sizes to within one size allows efficient anticipation by the orthopaedic surgeon.*

Keywords: *Total knee arthroplasty, Preoperative planning, Digital images*

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Preoperative planning is an important part of the surgical procedure. The technical goals of preoperative planning of the total knee arthroplasty (TKA) are to achieve the accurate prosthetic seating with proper axial alignment(1). Preoperative planning provides the correct prosthetic component sizes before surgery. Accurate preoperative templating to predict the implant size and position can facilitate the precise, efficient and reproducible total knee replacement operations. Many surgeons use preoperative planning to ensure availability of appropriate implants and predict bony resections. When templating is performed, it can identify extreme sizes that may require special order, and templating also can predict the size mismatches between femoral and tibial implants. When this information were known prior to performing procedures, these limitations can be accommodated during the surgical procedure or a different implant system can be chosen.

Standard preoperative templating for TKA has been performed with acetate overlays of the knee implants on appropriately magnified radiographs of the

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knee. TKA requires a good quality of anteroposterior and lateral images of the affected knee. Knee radiographs are obtained with the beam 40 inches from the X-ray plate. The magnification of the images is proportional to the distance of the bone from the plate. This magnification is generally 110%, but however it is affected by the actual distance of the bone from the X-ray plate[2].

Digital radiographs were found to gradually replace the conventional radiographs. Preoperative templating for TKA can also be performed with digital templates of the knee implants on digital radiographs of the knee[3]. In our institution, the digital templates are not available. Digital preoperative planning is then performed by measurement technique for predicting knee implant sizing.

The purpose of this study is to determine the accuracy of digital preoperative plans for predicting knee implant sizing by measuring technique.

Material and Method

A retrospective study was conducted in Ramathibodi hospital during July 2007 and March 2008. One hundred primary total knee arthroplasties were included. All patients underwent the primary arthroplasty with cemented total knee prosthesis by a single surgeon who had extensive experience more than 15 years. The patients were excluded from the study if they had a history of surgery of the region of interest, valgus knee, or if the clinically satisfactory radiographs for accurate measurements were unavailable for evaluation. After the exclusion of 19 interventions, 81 knee arthroplasties were planned. Nexgen LPS or Gender knees (Zimmer orthopaedics, Thailand) were used for all primary total knee arthroplasties. The femoral component and the tibial component were available in 8 sizes.

In our institution, all patients those were scheduled for total knee arthroplasty obtained the digital weight bearing anteroposterior and lateral radiographs of the knee. This image was calibrated to achieve 110% magnification. On the digital anteroposterior radiograph of the knee, the femoral intramedullary axis and the level of distal femoral resection were identified; the mediolateral diameter of femur was determined. The tibial intramedullary axis and the level of proximal tibial resection were identified and then the mediolateral diameter of tibia was determined (Fig. 1). On the digital lateral radiograph of the knee, the femoral intramedullary axis and the femoral anterior cortex were identified and the anteroposterior diameter of femur was determined. The tibial anterior cortex and the level of proximal tibial resection were identified, then anteroposterior diameter of tibia was determined (Fig. 2).

When digital preoperative planning was completed, the anteroposterior and mediolateral

Fig. 1 Anteroposterior radiograph of the knee. Radiograph showed the femoral intramedullary axis, planned distal femoral resection, mediolateral diameter of the distal femur, the tibial intramedullary axis, planned proximal tibial resection and mediolateral diameter of the proximal tibia

Fig. 2 Lateral radiograph of the knee. Radiograph showed the femoral anterior cortex, anteroposterior diameter of the distal femur, the tibial anterior cortex, planned proximal tibial resection and anteroposterior diameter of the proximal tibia

diameter of femur and tibia were compared with the anteroposterior and mediolateral diameter of the implant before the implant size was chosen. The results of the implants size of digital images were compared with the actual femoral and tibial implants used at the time of surgery.

Digital preoperative planning for predicting knee implants sizing on radiographs of 81 patients were performed by two different surgeons (one adult reconstruction fellow and one orthopaedic resident) to determine the interobserver reliability. The same radiographs were evaluated as the second time by the same surgeons (adult reconstruction fellow) approximately after three weeks to measure the intra-observer reliability for planning. The accuracy of these digital plans was determined by assessing the differences between the digital plans and the actual implant sizes by someone other than the actual surgeon, and which was not incorporated into the rest of the surgical procedure. To detect the systematic errors, the mean differences between the type of plan and the implant sizes were measured. The success rates of the digital preoperative plans were measured using two different cut-off points to define a correct plan; the exact matching, and the matching allowing for a difference of one size. The correlation coefficients were calculated to determine the interobserver and intraobserver reliability.

Results

Interobserver and intraobserver reliability were shown in the Fig. 3-10.

One hundred primary total knee arthroplasties (TKA) were included. Nineteen patients were excluded because two of them had previous surgery (HTO), 7 patients had valgus knee and 10 patients had radiographic film that could not identify the accurate landmark. The total primary total knee arthroplasty left

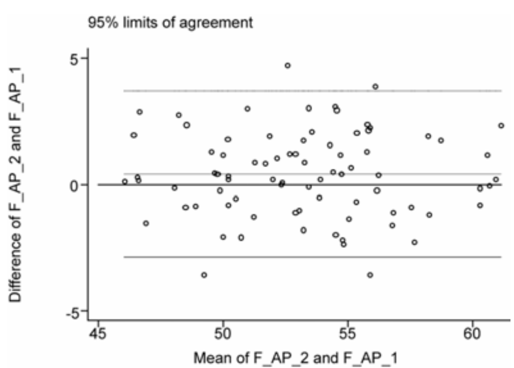

Fig. 3 Interobserver reliability of femur anteroposterior diameter

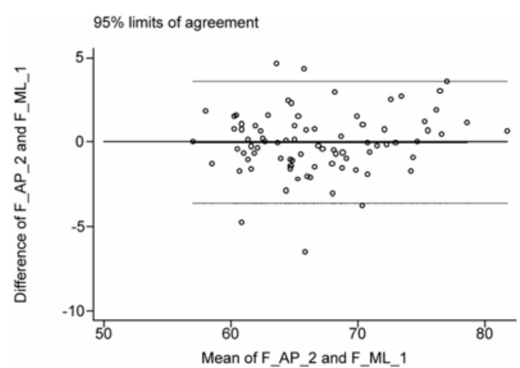

Fig. 4 Interobserver reliability of femur mediolateral diameter

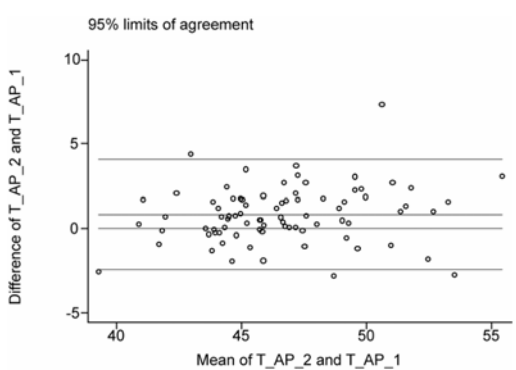

Fig. 5 Interobserver reliability of tibia anteroposterior diameter

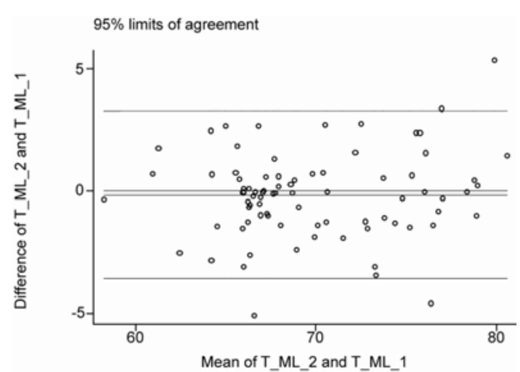

Fig. 6 Interobserver reliability of tibia mediolateral diameter

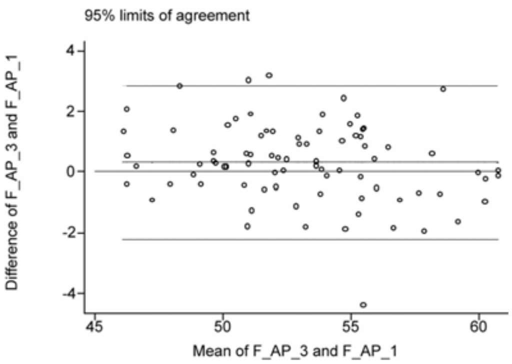

Fig. 7 Intraobserver reliability of femur anteroposterior diameter

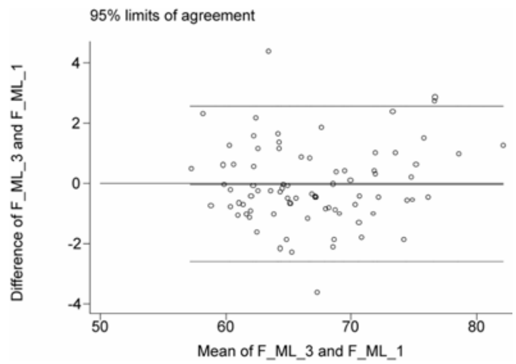

Fig. 8 Intraobserver reliability of femur mediolateral diameter

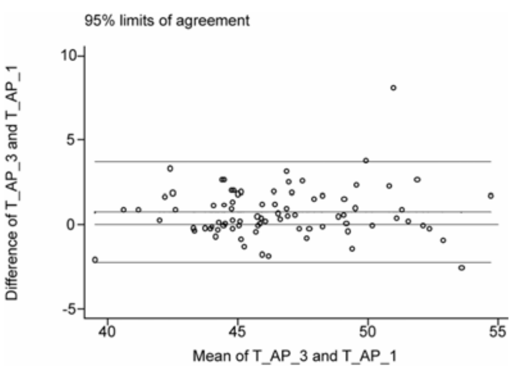

Fig. 9 Intraobserver reliability of tibia anteroposterior diameter

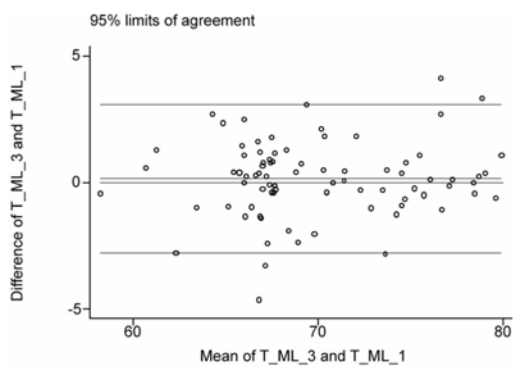

Fig. 10 Intraobserver reliability of tibia mediolateral diameter

in this study were 81. They were 7 men and 74 women. The average age of the patients was 68 $\pm$ 8.3 years.

The accuracy of digital preoperative plans for femoral component was 53.1%. The accuracy of digital preoperative plans for tibial component was 59.3%. The digital preoperative planning predicted 79 of 81 (97.6%) femoral implants to within one size and predicted 77 of 81 (95.1%) measurements of the tibial implants to within one size (Table 1).

Discussion

Many orthopaedic surgeons used pre-operative planning to predict implant sizes, to ensure available resources, and to prepare for expected and unexpected situations and education activities. We routinely use templating for many total knee arthroplasty procedures without knowing its accuracy in predicting knee implant sizes. Currently, our hospital changes the technic from the conventional radiograph to the digital one (PACS-Picture Archiving and Communication System). The precise implications for the costs and changed routines are unclear[4]. Even as without being able to foresee all the consequences, such changes seem to be able to offer the great advantages in terms of creating, storing, retrieving

Table 1. Error from implanted size

Error (sizes)	Femur (%)	Tibia (%)
-3	0	0
-2	1 (1.2)	0
-1	22 (27.2)	12 (14.8)
0	43 (53.1)	48 (59.3)
1	14 (17.3)	17 (21)
2	1 (1.2)	4 (4.9)
3	0	0

and analyzing images[5]. When radiographs were digitally acquired and calibrated, they could be readily manipulated and transferred among the radiology department, clinic, and operating room. One of our goals in evaluating the accuracy of digital preoperative planning for TKA was to prepare for the conversion to a completely filmless imaging system for our practice[6].

We found that the digital preoperative planning by measuring technique was accurate in predicting TKA implants. Using the implanted size as the gold standard, the previous studies suggested that the digital templating could predict implanted size exactly in 50% of cases and within one size in approximately 90% of cases[7]. Digital templates are not available in our hospital. We designed the method to predict implant size by measuring technique. In this study, it was shown that the accuracy of digital preoperative planning by measuring technique was equal to the accuracy of digital templates from the previous study. Digital preoperative planning using measuring technique of TKA in this sample group for both components scored better, with more than 50% exact agreements and more than 95% agreements when allowing an error of one component size. Interobserver reliability and intraobserver reliability had consistently higher scores. This means that it is generally more reliable to leave the choice of component sizes to the surgeon himself. This concept is consistent with the philosophy that the preoperative planning is part of the entire surgical procedure.

A number of limitations were caused by this study design. Firstly, we calculated the magnification of femur and tibia from 110% to 100% and then compared diameter of femur and tibia with the diameter of the implant. The magnification of the images was proportional to the distance of the bone from the plate. This magnification was generally 110%, but it was affected by the actual distance of the bone from the X-ray plate. Magnification could also be altered by increasing the soft tissue thickness or flexion contracture, both of which increase image magnification by increasing the bone to plate distance. The addition of a marker of a known size was placed at the same distance from the plate as the bone allow accurate calculation of magnification on each film. Secondly, in severe osteoarthritis of the knee, the rotation deformity might be present on the radiographic film. In this study, we used the distance between the cortex of predicted bone cut for calculating the implant size, thus the rotation of the knee affected the results. To decrease the error, we excluded the radiographic film that could not identify the accurate landmark from this study. Finally, we used the implanted component size as our gold standard. Nevertheless, we did not develop a consensus opinion about which implant size was the best for each patient.

Our data suggested that we could be confident in transition to the all-digital evolving techniques without the uncertainty accuracy or reliability comparing with the current method of acetate templating. This might allow us to eliminate the work and expense associated with acetate templating in terms of printing, tracking, and storing the x-ray film.

Further study will determine the accuracy of digital preoperative planning by measuring technique with the data of implant sizes from computer assisted surgery. The other interesting study should be on how much benefit could be obtained in clinical outcome if the digital preoperative planning became better developed, with added digital applications to enable biomechanical planning. Investigations will be required in the near future to determine these potential benefits.

Conclusion

Digital preoperative planning can help the physicians focus the judgments and plans the operation. When planning is performed, it can identify extremes of sizes that may require special order, and it can predict the size mismatches between the femoral and tibial implants. These limitations can be accommodated during the surgical procedure or by a different implant system chosen. Predicting implant sizes by measuring technique allows efficient anticipation by the orthopaedic surgeon.

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ความถูกต้องแม่นยำของการเลือกขนาดข้อเข่าเทียมโดยวิธีการวัดขนาดกระดูกจากฟิล์มเอกซเรย์

ศิวดล วงค์ศักดิ์, วิโรจน์ กวินวงศ์โกวิท, พรชัย มูลพฤกษ์, ธนพจน์ จันทร์นุ่ม, ภัทรวัณย์ วรธนารัตน์

ภูมิหลัง*: การวางแผนเพื่อหาขนาดข้อเข่าเทียมจากฟิล์มเอกซเรย์ก่อนการผ่าตัดจะช่วยให้การผ่าตัดข้อเข่าเทียมมีความถูกต้องแม่นยำและมีประสิทธิภาพ ซึ่งฟิล์มเอกซเรย์ในระบบ digital (PACS) สามารถนำมาใช้เพื่อหาขนาดของข้อเข่าเทียมได้*

วัตถุประสงค์*: เพื่อศึกษาความถูกต้องแม่นยำของการเลือกขนาดข้อเข่าเทียม โดยวิธีการวัดขนาดกระดูกจากฟิล์มเอกซเรย์ระบบ digital*

วัสดุและวิธีการ*: การเก็บข้อมูลย้อนหลังในผู้ป่วยจำนวน 100 คนที่มาทำการผ่าตัดเปลี่ยนข้อเข่าเทียมที่โรงพยาบาลรามาธิบดี ระหว่างเดือน กรกฎาคม พ.ศ. 2550 ถึง เดือน มีนาคม 2551 โดยวิธี retrospective study ผู้ป่วยที่ถูกคัดเลือกเป็นตัวอย่างในการศึกษาเป็นผู้ป่วยที่ได้รับการวินิจฉัยว่าเป็นข้อเข่าเสื่อมแบบเข่าโก่งที่ได้รับการผ่าตัดเปลี่ยนข้อเข่าเทียม ภาพเอ็กซเรย์ข้อเข่าในท่าตรงและท่าด้านข้างของผู้ป่วยจะถูกบันทึกในระบบ digital (PACS) เนื่องจากการวัดขนาดของข้อเข่าเทียมด้วย digital template ยังไม่ถูกนำมาใช้ในโรงพยาบาล ผู้ศึกษาจึงคิดวิธีการวัดขนาดของข้อเข่าเทียมโดยการคำนวณจากขนาดของกระดูกหลังจากวางแผนการตั้งองศาการตัดและระดับการตัดของกระดูกต้นขาและกระดูกหน้าแข้ง ข้อมูลที่ได้จากการวัดจะนำไปเลือกขนาดของข้อเข่าเทียม ซึ่งจะนำไปเปรียบเทียบกับขนาดข้อเข่าเทียมที่ใช้จริงในห้องผ่าตัด การแปรผลจะแปรผลเป็นความถูกต้องแม่นยำของการวัด การวัดโดยแพทย์ผู้ช่วยอาจารย์กับแพทย์ประจำบ้านเพื่อเปรียบเทียบค่า interobserver reliability และแพทย์ผู้ช่วยอาจารย์จะทำการวัดซ้ำในอีก 3 สัปดาห์ต่อมาเพื่อหาค่า intraobserver reliability*

ผลการศึกษา*: การวางแผนการผ่าตัดเปลี่ยนข้อเข่าเทียมในการเลือกขนาดข้อเข่าเทียมโดยวิธีการวัดขนาดกระดูกต้นขาจากฟิล์มเอกซเรย์ระบบ digital ให้ความถูกต้องแม่นยำร้อยละ 53.1 และวิธีการวัดขนาดกระดูกหน้าแข้งให้ความถูกต้องแม่นยำร้อยละ 59.3 ถ้ายอมให้มีความคลาดเคลื่อนของการวัดได้หนึ่งขนาดจะพบว่า ความถูกต้องแม่นยำของการวัดมากกว่าร้อยละ 95 นอกจากนี้ ยังพบว่าการเลือกขนาดข้อเข่าเทียมด้วยวิธีการวัดให้ความถูกต้องแม่นยำสูง ซึ่งจะช่วยแพทย์ผู้ผ่าตัดในการวางแผนการรักษา*

สรุป*: ในบางครั้งขนาดของข้อเข่าเทียมที่ได้จากการวางแผนการผ่าตัดอาจมีขนาดใหญ่กว่าหรือเล็กกว่าขนาดข้อเข่าเทียมที่เตรียมไว้ในห้องผ่าตัด การวางแผนจะทำให้แพทย์สั่งเตรียมเครื่องมือล่วงหน้าได้ ซึ่งการวัดโดยวิธีนี้ง่ายและสามารถทำได้โดยแพทย์กระดูกและข้อทั่ว ๆ ไป*