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REVIEW

Radiographic Evaluation of Alignment Following TKA, a Systematic Review

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ABSTRACT

Postoperative assessment is of paramount importance in primary total knee arthroplasty. A thorough postoperative analysis helps the surgeon anticipate any postoperative potential issues and correlate the preoperative planning with the postoperative result, and provides better understanding of the importance of surgical principles of primary total knee arthroplasty. In addition, postoperative analysis helps the surgeon understand surgical errors and improve future outcomes. Standard radiographs, with a known magnification, should be obtained for postoperative total knee arthroplasty evaluation. Although imaging evaluation of knee arthroplasty is usually limited to conventional radiographs, examples of the utility of computed tomography are also illustrated, and suggested imaging strategies discussed.

Keywords: total knee arthroplasty, radiographic evaluation, TKA alignment, long-leg radiographs, Roentgenographic evaluation

INTRODUCTION

Total knee arthroplasty (TKA) is an increasingly common procedure; the number of procedures performed in the last two decades has increased with 162% (1). It is projected that the number of revisions will increase by 600% between 2005 and 2030 (2). Although excellent functional outcomes and long-term survival rates have been reported, infection, instability, wear, osteolysis, mechanical loosening, and periprosthetic fracture are common causes of TKA revision TKA (3). Many of the failures are related directly to the surgical technique and are under the control by surgeon. Thorough preoperative planning is critical in optimizing implant position and soft-tissue balancing, which will minimize the probability of subsequent TKA failure and improve the surgical outcome (4). In addition, postoperative evaluation helps the surgeon to better understand the procedure and thereby improve future results. Accomplishment of limb alignment and the balance of soft tissues are the main objectives of the surgeon at the end of TKA. Alignment of TKA should be performed and measured in all spatial

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planes. The aim of this paper is to review existing described methods for measuring postoperative TKA alignment in all three planes.

Definition of planes

Sagittal plane (lateral) is defined by any vertical, longitudinal plane through the body that is parallel to the median plane. The vertical, longitudinal plane at right angles to the sagittal plane, and dividing the body into anterior and posterior portions is called the coronal (frontal) plane. The horizontal plane refers to a plane at right angles to both median and coronal planes, this is called the axial (transverse) plane.

Standard postoperative assessment

Postoperative measurements of TKA alignment are done by assessing the relative position of components to the femur and tibia. The "Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System" has been developed to uniform radiographic reports of TKA's (5). In addition, Knee Society (KS) scoring system has a numerical score that evaluates the fixation of the implants. Prosthetic position is evaluated with angle measurements. Position of the components is evaluated in the coronal and sagittal plane with angles resulting between the component and the longitudinal mid-medullary lines on a 91.44 cm cassette roentgenogram. This system provides uniform data collection using different implant types. A study evaluated this system (6). The authors concluded that single component angles analyzed using KS system has sufficient reproducibility to be used in the clinical practice, while the method for assessing the patellar shift and height, as for radiolucent lines should be reconsidered. The improvements in TKA positioning has been brought by new technologies such as computer navigation or patient specific instrumentation, has proven the need of higher evidence of precision than those obtained by simple analysis of two short limb X-rays. ❑

CORONAL PLANE EVALUATION (FRONTAL)

Patient positioning

Patient positioning is crucial to obtain a good accuracy in TKA evaluation in a coronal plane. A multitude of studies analyzed the influence of knee flexion or the rotation of the lower limb over the measurements in coronal plane (7-10). External rotation of the lower limb will increase the varus angle of the knee and the internal rotation will decrease this tendency. The magnitude of those variations is amplified if the knee extension is incomplete. Jiang and Insall demonstrated a 2.5° modification of angulation in malrotations that was between 20° external rotation and 20° internal oration (11). Oswald calculated on cadavers a modification of 0.2° for every 5° of internal or external rotation of the lower limb (9). This is because of the femoral bowing in sagittal plane. Tibial deformities in this plane are less frequent (8, 9).

An anteroposterior (AP) radiography of the lower limb is necessary, which is obtained using a 129 x 36 cm film (14 x 151 inch). In digital radiology, images are obtained at three different levels, using three different films, 5 x 43 cm each (14 x 17 inch). The lower limb must be fully extended, and the tibial tuberosity and patella (without subluxation) should look forward. The most frequent error is the placement of the lower limb in external rotation. This can be avoided by aligning the second metatarsal bone perpendicular to the plate (7). The legs could be close to each other, preferably at 30 cm one to the other just to be sure that the tibia is vertical and it looks forward with neutral rotation (12). The X-ray is centered at the knee joint at 240 cm (8 feet). An anteroposterior weight bearing x-ray image is preferable after TKA because it allows an extensive analysis of the magnitude and the origin of the malposition. The AP weight bearing radiology of the lower limb for a malposition TKA will give us information about the soft tissues, the convex side being under tension.

Short *versus* long-leg radiographs

Frontal plane X-ray evaluation of the KS roentgenographic evaluation and scoring system is done on a short AP knee film (4x17 inch cassette). In the KS form, an anatomic FT angle called Total Valgus Angle is obtained with the sum of the femoral anatomic angle alfa and tibial anatomic angle beta. The form considers angles calculated it short and long films. Angles alpha and beta are not clearly defined in this form. Angle alfa, as depicted on the KS form, is an anatomic femoral angle, which is formed between a tangent line to the medial and lateral condyles of the femoral component in extension and a distal femoral anatomical line. Angle beta, as depicted on the KS form, is an anatomic tibial angle which is formed between a tangent line to the tibial component baseplate in extension and the proximal tibial anatomical line. This angle calculation is not taking into account the influence of ligamentous laxities on radiographs and has several inherent inaccuracies. Standard short knee radiographs offer a limited distance above and below the knee to plot an axis for measuring the tibiofemoral angle. In some instances, the radiographic plate is not even centered precisely at the joint line level. This provides only a short segment on one side of the joint arthroplasty to plot the anatomical axis. In these instances, the anatomical axis of the femur and/ or tibia may not be collinear with a point equidistant from the conical margins 10 cm above or below the joint (13). Bowing of the femur and/or the tibia beyond that portion of bone revealed on short radiographs is the primary source of error of the measurements (14). Younger developed a mathematical formula using trigonometry to determine the position of the knee with respect to the mechanical axis a short film is used. This calculation is based on data obtained from a preoperative long film where the axis is drawn and calculated. The purpose of their equation was to determine the postoperative position without having to repeat the long-leg radiograph (15). In a recent study by Skytta *et al*., the standard AP knee radiograph appeared to be a valid alternative to the hip to-ankle radiograph for determining knee coronal plane alignment in routine follow-up after TKA (16).

However, the hip-to-ankle radiograph alone provides accurate information on weight-bearing mechanical axis in patients with suspected lower limb malalignment. The authors concluded that they recommend assessing the mechanical axis after TKA with a long-leg radiograph at least once. However, the long-leg radiographs should be replaced in routine follow-up by standard knee films which involve less radiation and costs. In case of conflicting clinical and radiographic findings, they recommended the use of long-leg radiographs (16). Computer-assisted TKA literature has recently criticized the reliability of long-leg radiographs in measuring postoperative TKA alignment (17-19). Many papers demonstrated the reliability of properly performed long-leg radiographs. Recently, the paper by Skytta *et al*. criticized previous studies which have inappropriately used correlations to assess the reproducibility of the hip-to-ankle radiographs (20). They determined the reliability of the hip-to-ankle radiograph using a sophisticated statistical method through a Bland-Altman analysis. Two consecutive hip-to-ankle radiographs were obtained in 52 patients after TKA. There was an excellent agreement between mechanical axis angles, tibiofemoral angles, and femoral and tibial component alignment in the two radiographs. There was also an excellent agreement between all intra- and inter-observer analyses. The hip-to-ankle radiograph appeared to be a reliable and reproducible means for determining the alignment of the knee in the coronal plane after TKA (20). Oswald and Jakob performed a comparison between long-leg radiographs and computerized calculations of angles on CT scans on a series of 38 bones. This showed a high precision of measurement on standard radiographs in neutral rotation and on bones without osteoarthritic deformations. The authors assumed that preoperative planning, and postoperative TKA measurements on long-leg radiographs, is very precise if neutral rotation of the affected limb is guaranteed (9).

Axis evaluation

The measurement in coronal plane after total knee arthroplasty are much easier than in an osteoarthritic knee, because the geometrical center of the knee has much easier landmarks to recognize, being in the center of the tibial and femoral component. For each bone, a mechanical axis (the axis between the centers of proximal and distal articulations) and anatomical axis (an axis which passing through the middle of the bone shaft) must be identified. The mechanical axis of the lower limb [hip-knee-ankle (HKA)] and an anatomical axis (FT) can be calculated.

The following axes and angles are belonging to the standard evaluation of the TKA after surgery in coronal plane:

1. Femoral mechanical axis (FMA) is the axis between the center of the femoral head and the center of the trochlear notch of the femoral component.

2. Tibial mechanical axis (TMA) is the axis between the center of the talus and the center of the tibial component.

3. The hip-knee-ankle angle (HKA) is the angle between the mechanical axis of the femur and the mechanical axis of the tibia.

4. The mechanical axis of the lower limb (MA) is the axis between the center of the femoral head and the center of the talus.

5. Mechanical axis deviation (MAD) is the perpendicular axis which is drawn from the MA to the center of the knee. The relationship between MA and the center of the knee, identified as MAD, is linear. This can be calculated using trigonometry. For every 1° of valgus or varus, the MA moves for about 5 mm away from the center of the knee.

Anatomical axis of the femur

It is the axis between two points across the femoral shaft. There are several ways to determine this axis. There is no consensus in this regard.

1. Moreland method

First point is localized at the intersection between the length of the femur from proximal to distal (a line drawn from the superior pole of the femoral head to the distal region of the internal condyle) and the femoral mediolateral thickness at the femoral shaft. The second point is localized at 10 cm proximal to the knee joint at the half of the mediolateral distance. In a normal femur, this axis extended proximal, it passes through piriformis fossa and distal it crosses the joint just 1cm medial from the center.

2. Paley method

The anatomical axis of the femur is found along the middle of the femoral shaft. The points are found in the center of the right femoral shaft proximally and distally.

3. Coventry method

It defines the anatomical axis as a line drawn between the center of the knee (the middle of the tibial intercondylar eminence, the midrange of the intercondylar notch) and the intersection between femoral neck axis and the anatomical axis of the proximal femur.

The alfa femoral angle (correspondent of the Paley's medial distal femoral angle (mdfa)) is the angle formed between a line formed by the femoral condyles of the femoral component in extension and a distal femoral anatomical axis.

The femoral anatomical mechanical angle (f ama) is the angle formed between the anatomical axis and the mechanical axis. Those two axes intersect on the knee joint when the rotation of the femur is neutral. In a 20° of external rotation, the intersection appears at 4 cm distal to the femur and 1 cm for 10° of external rotation. In 20° of internal rotation, the intersection is located at 5.1 cm proximal to the femoral condyles and 3.3 cm proximal to the femoral condyles for a 10° of internal rotation (8). Based on those results, Jiang and Insall created a diagram with the angles of correction suggested for every femoral anatomical mechanical angle based on different degrees of rotation of the femur calculated in relationship with the area where the intersection of the axes occur.

Anatomical axis of the tibia

Most authors support the idea that the anatomic axis of the tibia is one with the mechanical one (9, 12, 13).

1. Palley method

The anatomical axis of the tibia follows the middle of the tibial shaft. The axis goes from the middle of the tibial plateau, ending in the middle of the tibial plafond. According to Palley, the mechanical and anatomical axes are parallel but not the same. The anatomical axis crosses the knee joint slightly medial (10±5 mm) at the medial side of the intercondylar eminence. The distal end of the anatomical axis is crossing the talus at 4±4 mm medial from its center.

2. Oswald method

The anatomical axis is defined as a line that goes through center of the tibial plateau and the middle of the tibial shaft at 20 cm distance from the tibial plateau. The beta tibial angle (corresponding to Paley's anatomical medial proximal tibial angle) (6, 21, 22) is the angle formed between the tangent line at the base of the tibial component in extension and the anatomical axis of the tibia.

Tibio-femoral angle is an angle formed between the tibial and femoral anatomical axis. ❑

CONCLUSIONS

Measurements of lower limb alignment after TKA require knowledge of radiographic landmarks in the three planes. Conventional radiographic assessment can be obtained only with a series of proper films made with accurate technique and patient positioning. Multiple references for axes description are reported in literature. This variability is a natural consequence of the multitude of sizes, shapes and deformities, which is typical of the human skeleton. A disciplined approach radiographic analysis of the knee allows the surgeon to accurately plan the procedure and obtain a high range of information which can be transferred into the surgical field. Postoperatively, TKA assessment needs accurate measurements in order to understand the influence of surgical technique on clinical and functional results. However, all these measurements have a limit: they are bidimensional. ❑

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REFERENCES

1. **Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR.** Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991-2010. *JAMA* 2012;12:1227-1236.
2. **Kurtz S, Ong K, Lau E, Mowat F, Halpern M.** Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;4:780-785.
3. **Bozic KJ, Kurtz SM, Lau E, et al.** The epidemiology of revision total knee arthroplasty in the United States. *Clin Orthop Relat Res* 2010;1:45-51.
4. **Kniesel B, Konstantinidis L, Hirschmüller A, Südkamp N, Helwig P.** Digital templating in total knee and hip replacement: An analysis of planning accuracy. *Int Orthop* 2014;4:733-739.
5. **Ewald FC.** The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. *Clin Orthop Relat Res* 1989;248:9-12.
6. **Bach CM, Steingruber IE, Peer S, et al.** Radiographic assessment in total knee arthroplasty. *Clin Orthop Rela Res* 2001;385:144-150.
7. **Hunt MA, Fowler PJ, Birmingham TB, et al.** Foot rotational effects on radiographic measures of lower limbalignment. *Can J Surg* 2006;49:401-406.
8. **Jiang CC, Insall JN.** Effect of rotation on the axial alignment of the femur. Pitfalls in the use of femoral intramedullary guides in total knee arthroplasty. *Clin Orthop Rela Res* 1989;248:50-56.
9. **Oswald MH, Jakob RP, Schneider E, et al.** Radiological analysis of normal axial alignment of femur and tibia in view of total knee arthroplasty. *J Arthroplasty* 1993;8:419-426.
10. **Swanson KE, StocksGW, Warren PD, et al.** Does axial limb rotation affect the alignment measurements in deformed limbs? *Clin Orthop Relat Res* 2000;371:246-252.
11. **Jonsson K, Boegard T.** Radiography. In: *Imaging of the Knee.* Davies AM, Cassar-Pullicino VN (eds), New York: Springer, 2002.
12. **Hsu RW, Himeno S, Coventry MB, et al.** Normal axial alignment of the lower extremity and load-bearing distribution at the knee. *Clin Orthop Relat Res* 1990;255:215-227.
13. **Abdel MP, Oussedik S, Parratte S, et al.** Coronal alignment in total knee replacement: historical review, contemporary analysis, and future direction. Review article. *Bone Joint J* 2014;96-B(7):857-862.
14. **Bellemans J, Colyn W, Vandenneucker H, Victor J.** The Chitranjan Ranawat award: Is neutral mechanical alignment normal for all patients? The concept of constitutional varus. *Clin Orthop Relat Res* 2012;1:45-53.
15. **Dossett HG, Swartz GJ, Estrada NA, LeFevre GW, Kwasman BG.** Kinematically versus mechanically aligned total knee arthroplasty. *Orthopedics* 2012;35(2):e160-e169.
16. **Skytta ET, Lohman M, Tallroth K, et al.** Comparison standard anteroposterior knee and hip-to-ankle radiographs in determining the lower limb and implant alignment after total knee arthroplasty. *Scand J Surg* 2009;98:250-253.
17. **Chung BJ, Kang YG, Chang CB, et al.** Differences between sagittal femoral mechanical and distal reference axes should be considered in navigated TKA. *Clin Orthop Relat Res* 2009:467:2403-2413.
18. **Rauh MA, Boyle J, Mihalko WM, et al.** Reliability of measuring long-standing lower extremity radiographs. *Orthopedics* 2007:30:299-303.
19. **Yaffe MA, Koo SS, Stulberg SD.** Radiographic and navigation measurements of TKA limb alignment do not correlate. *Clin Orthop Relat Res* 2008;466:2736-2744.
20. **Skytta ET, Haapamaki V, Koivikko M, et al.** Reliability of the hip-to-ankle radiograph in determining the knee and implant alignment after total knee arthroplasty. *Acta Orthop Belg* 2011;77:329-335.
21. **Alizadeh RI, Eckhoff DG, Samson MM, et al.** Axial and rotational alignment of the leg. *Biomed Sci Instrum* 2004;40:290-296.
22. **Paley D, Herzenberg JE, Tetsworth K, et al.** Deformity planning for frontal and sagittal plane corrective osteotomies. *Orthop Clin North Am* 1994;25:425-465..