



# Clinico-radiological results in the alignment of prosthetic components after knee arthroplasty. A single-center observational study.

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## Abstract

**Introduction:** The complex biomechanics of the knee make it challenging to achieve a result close to natural anatomy after arthroplasty. The size and positioning of the implant affect the postoperative outcome, so its malrotation leads to weakness, instability, and loosening. The study's objective was to determine the angles of rotational alignment of the prosthesis and the clinical-functional results of the prosthesis.

**Methods:** The present observational study was conducted at the Alcívar Hospital in Guayaquil, Ecuador, from 2021 to 2022 with patients who underwent knee arthroplasty. The variables were sex, age, axis of rotation, and functional and clinical results. The sample was nonprobabilistic. Descriptive statistics were used.

**Results:** Forty-six cases were studied, 52.2% of whom were women, with an average age of 68.9. A total of 78.3% presented varus deformity, with an average shortening of 14.78 mm. A significant correction of the deviation was evidenced with angles  $\alpha$ ,  $\beta$ ,  $\chi$ , and  $\delta$  within normal parameters at 94.3%, 90.7%, 91.4%, and 88.6%, respectively. Additionally, an average internal rotation of the femoral component of 3.42 and tibial component of 25.84 degrees was obtained, with effectiveness in surgical technique of 47.8 and 23.9%, respectively.

**Conclusions:** 2D CT is a very reliable tool to identify the degree of effective functional rotation of the limb. No complications related to mechanical loosening were reported.

## Keywords:

**MeSH:** Arthroplasty, Replacement, Knee; rotation; Tomography.

## Abbreviations

Etc: Clinical Transepicondylar Axis  
ETq: surgical transepicondylar axis.  
CT: computed tomography.  
TKA: total knee arthroplasty

## Supplementary information

No supplementary materials are declared.

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## Author contributions

Hugo Villarroel Rovere: Conceptualization, data curation, formal analysis, fundraising, research, writing - original draft.  
Carlos Jaramillo Becerra: Conceptualization, data curation, formal analysis.  
Carlos Valle Ochoa: Acquisition of funds, research, methodology, resources, supervision.  
Andrea Adrián: Validation, visualization, writing - original draft, and writing - review and editing.

All the authors have read and approved the final version of the manuscript.

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## Availability of data and materials

Not declared.

## Introduction

The biomechanics and complex geometry of the knee make it challenging to achieve a result close to natural anatomy after primary total arthroplasty. Prosthetic replacement aims to relieve pain, provide stability and restore joint ranges to achieve functional improvement and optimize the patient's quality of life.

In total knee arthroplasty, the size and positioning of the implant affect the postoperative outcome. A slight displacement affects the contact of the components and the tension of the ligaments. This leads to altered mechanical behavior, including weakness, instability, and loosening of the arthroplasty.

The maximum stresses on the pelvic limb occur in monopodial support when the line of gravity that starts from what is considered the center of gravity in the fourth lumbar vertebra comes to fall to the center of the tibiofibular mortise.

Except for cases in which valgus deformity occurs, the arthritic knee moves in varus due to the predominance of medial solicitations, so the resultant forces fall on the medial compartment [1]. The integrity of the menisci, axial balance, and load savings are the main protective factors of the knee joint; however, these factors are altered with age, producing a progressive degenerative process [2] until limiting daily activities associated with intense pain conditions and the need for joint replacement with the respective surgical correction of the load axes for the optimization of joint biomechanics.

Limb rotation depends on femoral anteversion, proximal tibial, distal femoral rotation, tibial diaphyseal rotation, and tarsal and metatarsal rotation.

The usual lower extremity alignment diagrams estimate that the femoral anatomical axis intersects the mechanical axis in the center of the knee when it frequently does so in the supracondylar region. The mean angle between these axes is 6°, and their intersection will be distal to the femoral condyles when the femur is in external rotation and proximal to them when it is in internal process. Hence, the distance between this point of intersection and the joint line gives a reference to the rotation of the limb.

This rotation of the lower limbs affects the radiographic measurement since knee flexion produces an external process that increases varus and internal rotation accentuates valgus up to 8° between 20° of external course and 20° of internal rotation. Therefore, the rotational position of the femoral implant must be considered to estimate the physiological valgus. The flexion stability and kinetics of the femoropatellar joint will depend on the rotational alignment of the prosthetic femoral component [3].

The problem lies in establishing anatomical references to calibrate the degree of distal femoral external rotation when the involvement of the femoral condyles usually constitutes a valid reference in primary arthroplasty. However, the orientation of the implants in the horizontal plane is carried out with fewer anatomical references and without precise radiographic measurement, so their correct placement depends to a greater extent on the surgeon's experience [4].

The resulting rotational alignment is essential for the future of the joint itself and the neighboring joints, the extensor apparatus's kinetics, and the crucial function of the lower limb: gait [5]. The objective of this study was to determine the alignment of the prosthetic components based on postoperative radiological and tomographic measurements to determine the clinical-radiological results and assess the effectiveness of the usual surgical technique for the rotational orientation of the implant.

## Materials and methods

### Study design

The present study is cross-sectional. The source is retrospective.

### Scenery

The study was carried out in the image and archive service of the Alcívar Hospital in Guayaquil, Ecuador. The study period was from July 1, 2021, to July 1, 2022.

### Participants

Patients of legal age diagnosed with grade III and IV osteoarthritis of the knee who underwent primary total knee arthroplasty and underwent clinical and radiological control for a minimum period of 6 months were included. Cases with incomplete data were removed from the analysis. Patients with a clinical and imaging diagnosis of knee osteoarthritis treated with unicompartamental knee arthroplasty were excluded. Patients who did not continue clinical and radiological controls or who did not report pre- and postoperative measurements to determine the rotation of the prosthetic components were excluded. Patients with immediate or acute postoperative complications unrelated to rotational alignment were also excluded.

### Variables

The variables were age and weight of the patient, sex, angular deformity, degree of osteoarthritis using the Kellgren and Lawrence scale, and presence of associated pathologies. Postintervention joint functionality was additionally assessed using the Knee Society Score (KSS) as a reference, which

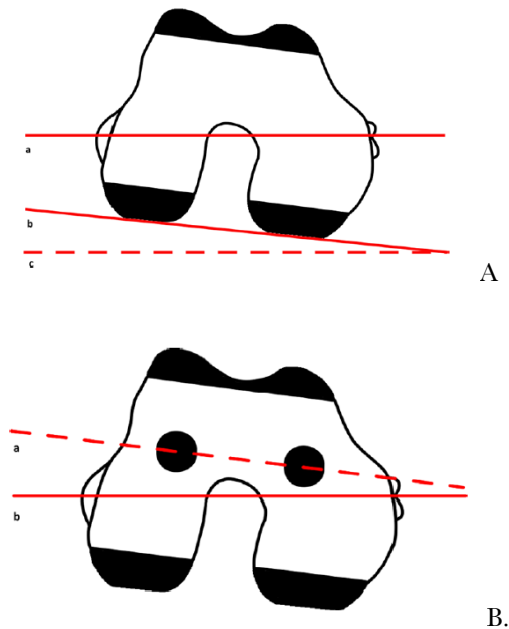
covers the following parameters: pain, range of motion, flexion contracture, delay in full extension, alignment of load axes, anterior, posterior, and mediolateral stability, functionality when walking or climbing stairs, and use of supports for ambulation [6].

### Data sources/measurements

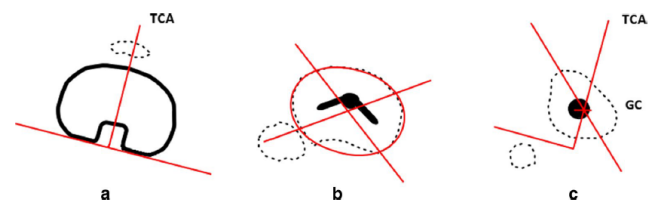
The source was indirect; an electronic form was filled out from the data of the institutional clinical history of the patients who entered the hospitalization period. A review of the traumatology and imaging unit registry was carried out to recruit cases. The information was treated confidentially; personal data that would allow the identification of the study subjects were not included. Imaging studies were performed with a 16-slice Hitachi Supria tomograph in 2021 and later with a 128-slice Phillips Incisive CT PRO (2022). Patients are examined in the supine position to study rotational alignment. The usual radiological projections of the knee and patella were performed, in addition to a scan on the lower extremities of approximately 140 cm in length with a voltage of 100 kilowatts and an average intensity of 250 milliamperes.

Rotation of the femoral component was defined by the epicondylar axis concerning the posterior condylar line by a 2D tomographic study [7], while transposed axial CT images of the tibia with different points were used for assessment of tibial component rotation reference anatomical components considering the interindividual variability of the patients, since this method is fast and provides the most precise measurement, even though a cutoff point still needs to be established to support the review of said components. The reference points used for measurement were the posterior edge of the tibial component about the geometric center and the tibial tubercle [8]. Below are some examples of the technique used to evaluate the position of the prosthetic parts (Figure 1 to Figure 7).

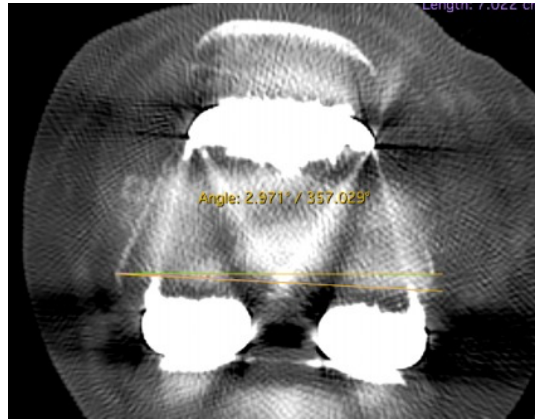
**Figure 1.** Schemes for measuring angles of rotation of femoral and tibial prosthetic components. A: Axial rotation of the femoral component to the surgical epicondylar axis (a, c) and posterior condylar line (b). B: Axial rotation of the femoral component relative to the line through the femoral fixation pegs (A) and the epicondylar axis (B).



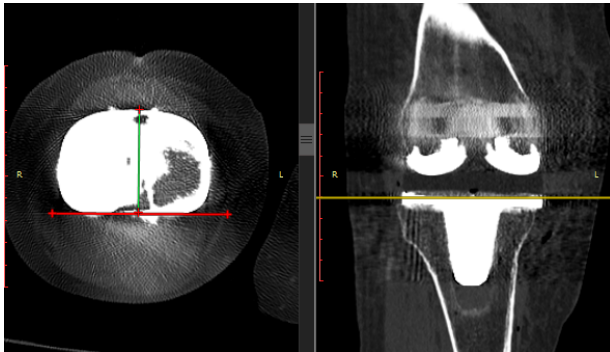
**Figure 2.** Three slices of the CT scan are required to define the rotational position of the tibial component relative to the tibial tubercle. The most proximal slice of the CT scan passes through the component and limits the tibial component angle (TCA). B Immediately distal to the component, a second cut is used to establish the geometric center of the proximal tibia. C The most distal amount is made through the tibial tubercle. Data from the two previous images are superimposed on this image: (1) the geometric center and (2) the TCA. A line is drawn from the apex of the tubercle to the geometric center. The angle subtended by this line and the TCA is the position of rotation of the tibial component.



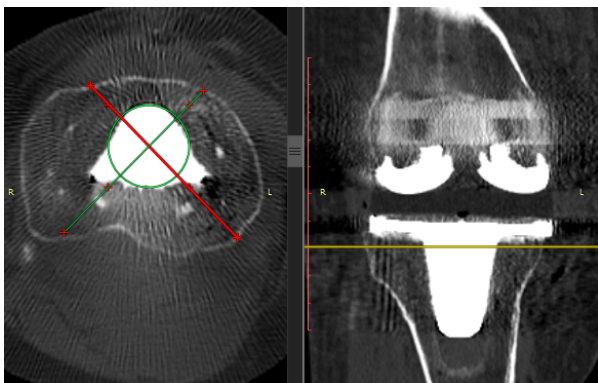
**Figure 3.** Measurement of angles of rotation of femoral and tibial prosthetic components by CT. Axial rotation of the femoral component about the surgical epicondylar and posterior condylar axes with a grade of  $2.9^\circ$ .



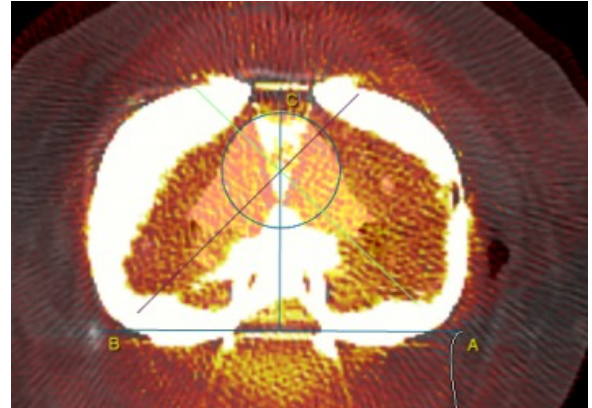
**Figure 4.** CT slices determine the rotational position of the tibial component with the tibial tubercle. Image A shows the proximal cut passing through the element and defining the tibial component angle (TCA).



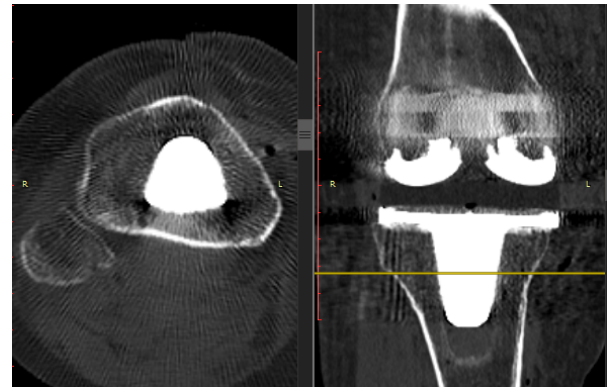
**Figure 5.** The image is a slice immediately distal to the component used to establish the geometric center of the proximal tibia.



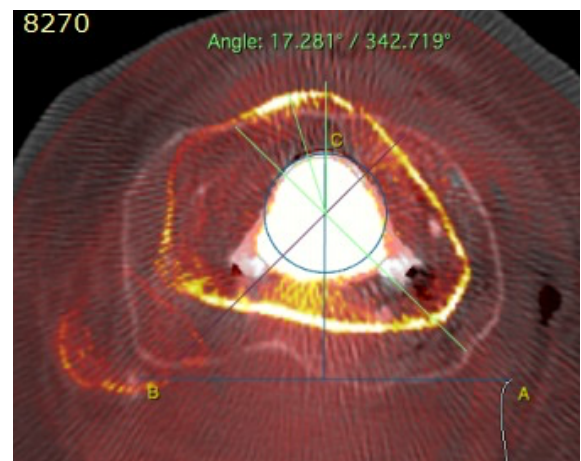
**Figure 6.** Image C shows the fusion of images 4 and 5.



**Figure 6.** Image D shows that the most distal cut is made through the tibial tubercle.



**Figure 7.** Image E is a fusion of the previous slices: the geometric center, the TCA, and the angle subtended by this line, and the TCA is the position of rotation of the tibial component, which is  $17.2^\circ$ .



### Biases

The principal investigator kept the data with a guide and records approved in the research protocol to avoid interviewer, information, and memory biases. Observation and selection bias was avoided by applying the participant selection criteria. Two researchers independently analyzed each record in duplicate, and the variables were recorded in the database once their concordance was verified.

### Study size

The sample was nonprobabilistic, of the census type, where all possible cases of the study period were included.

### Quantitative variables

Descriptive statistics were used. The results are expressed on a scale of means and standard deviations. Categorical data are presented in proportions.

### Statistical analysis

Noninferential statistics are used, using proportions and frequencies. The statistical package used was SPSS 27.0 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp).

## Results

### Participants

The study included 46 patients with cemented primary total knee arthroplasty using standardized conventional prostheses from Servimed and Biomet. Twenty-nine incomplete cases were excluded from the analysis due to a lack of clinical or radiological control records.

### Study group characteristics

There were 24 women (52.17%) and 22 men (47.83%). The average age of the group was 68.9 years. Twenty-five left knee arthroplasties (54.35%) and 21 right knee arthroplasties (45.65%) were performed.

### Description of load axes

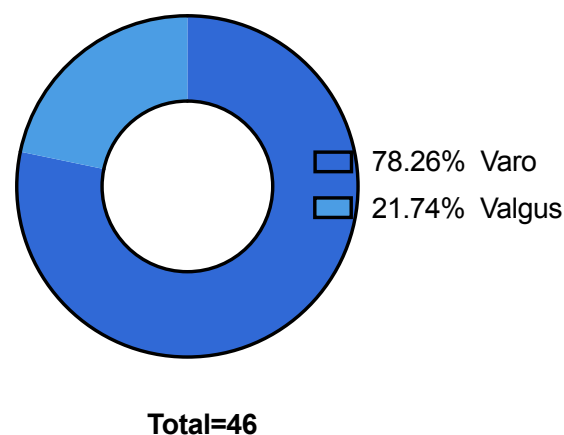
There was significant variability in the angles to be corrected at the level of the affected limb, with a minimum of 0.9 degrees in varus, a maximum of 27.8 degrees in varus, and an average of 10.9 degrees. The deformity most commonly associated with severe gonarthrosis was varus, with 78.26%, while valgus deformity represented 21.74% (Table 1 and Figure 8).

**Table 1.** Description of load axes (Valgo and Varus) pre and postoperative.

		Preopera- tive n=46	Postopera- tive n=46
Valgus	Physiological	5 (10.87%)	10 (21.74%)
	Mild (10-15 °)	0 (0%)	0%
	Moderate (16-19 °)	3 (6.62%)	0%
	Severe > 20 °	2 (4.34%)	0%
Varus	Physiological	8 (17.39%)	28 (60.87%)
	Mild (5-10 °)	13 (28.26%)	8 (17.39%)
	Moderate (11-20 °)	12 (26.09%)	0
	Severe > 20 °	3 (6.62%)	0
AC	<10 mm	24 (52.17%)	-
	10.1 – 30 mm	14 (30.43%)	-
	30.1 – 50 mm	7 (15.22%)	-
	> 50 mm	1 (2.17%)	-

AC: Shortening or difference between extremities.

**Figure 8.** Deformity associated with osteoarthritis of the knee



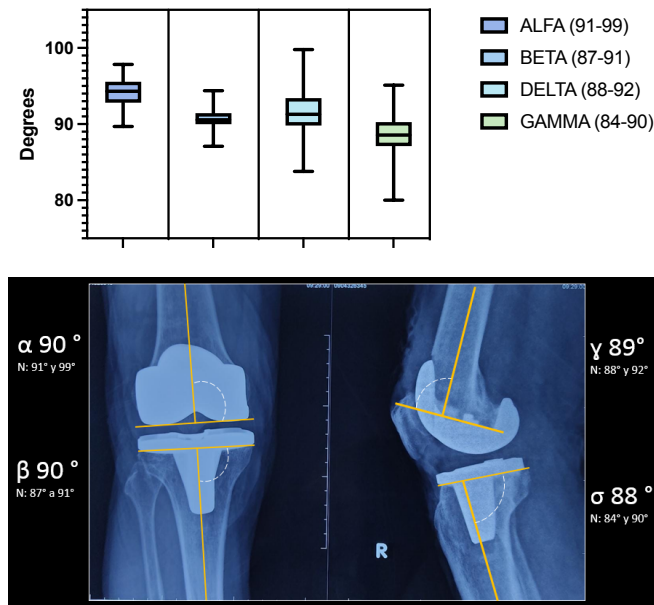
### Limb length

A large part of the study population presented discrepancies in the length of the pelvic limbs associated with wear of the chondral surface, decrease or total loss of joint space, formation of subchondral cysts, and compromised bone stock. On average, 14.78 mm between both lower limbs was found, with the most significant discrepancy to be corrected being 66 mm. Table 1 shows the variability in the contrast of the lower limbs observed in the population under study.

### Determinations of alpha, beta, gamma, and delta angles.

The alpha angle was determined within normal parameters in 94.26% of the population, the beta angle in 90.71%, the delta angle in 91.42%, and the gamma angle in 88.59% (Figure 9).

**Figure 9.** Angle measurements ( $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ ) in post-surgical radiological projections.



### Knee tomography (2D).

Alpha angle determination within parameters was obtained. The axis of the prosthetic component had an average internal rotation of 3.42 degrees (minimum of 1.3 degrees and maximum of 6.49 degrees inward). After the intervention, the surgical technique was evaluated in terms of the tomographic measurements, obtaining a relationship of 47.8% for the femoral prosthetic component placement, represented by 22 patients operated on with a rotation angle within normal parameters of the studied population. Figure 10 shows the measurements of the rotation angles for the prosthetic tibial component, which report a mean of 24.49 degrees and an average of 25.84 degrees, with a minimum of 11.5 and a maximum of 43.9 degrees.

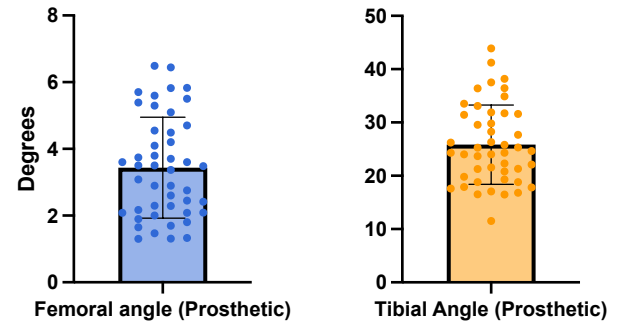
When evaluating the surgical technique applied to the tomographic measurements, a relationship of 23.91% was obtained for the placement of the tibial prosthetic component.

### Postoperative clinical evaluation

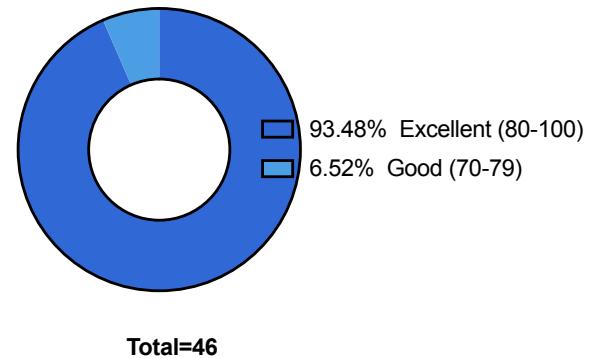
According to the KSS scale of the Knee Society, the rating of the postoperative clinic was excellent in 43 cases (93.5%), and

the functional assessment was excellent in 43 patients (93.5%) (Figures 10, 11, and 12).

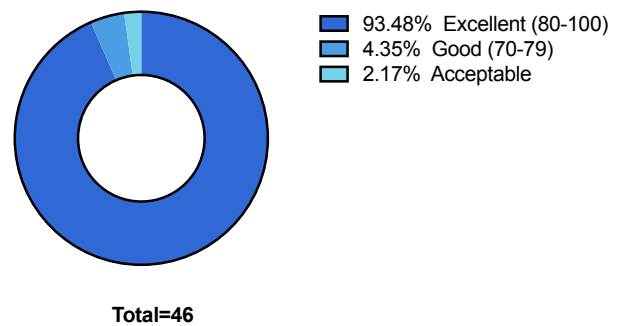
**Figure 10.** Femoral and Tibial angles.



**Figure 11.** KKS for clinical outcome



**Figure 12.** KKS functional scale



### Discussion

In total knee arthroplasty, the size and positioning of the implant affect the postoperative outcome. A slight displacement affects the contact of the components and the tension of the ligaments. This leads to altered mechanical behavior, including weakness, instability, and loosening of the arthroplasty. Patellofemoral complications and joint instability are seen in 35% of cases 5 years after total knee arthroplasty [9]. The

positioning of the implant components in the axial plane is called rotational alignment. Poor postoperative results, such as the persistence of pain, instability or functional alteration, and the incidence of significant complications, are related to errors in the rotational alignment of the components.

The present study demonstrates that computerized axial tomography is a valuable method for determining the angles of rotation of prosthetic components, which makes it possible to predict functionality and the percentage of revision in the medium and long term.

Currently, a consensus has been reached regarding the anatomical references for measuring the angles of rotation of the femoral prosthetic component; however, there still needs to be more variability regarding the concerns for measuring the tibial component.

A study by Berger et al. [10] used multiple nonaligned transposed axial CT images of the tibia with different landmarks. However, they concluded that this method is considered less accurate since the position of the leg during the scan can influence the appearance of the epicondylar axis.

Additionally, they indicate that using 3D reconstructed images solves this problem, and the entire leg must be considered to correctly measure the alignment of the tibial and femoral components.

In another study conducted by Kim et al. [11], tomographic measurements were performed; however, they did not refer to anatomical landmarks. In all cases, they used mobile bearing rotation platform prostheses. Rotation of the tibial component was defined as the angle formed by a line along the posterior margin of the tibial plateau and another line along the posterior margin of the tibial pad. They stated that the mobile nature of the tibial bearing may affect the proper rotational alignment of the tibial component.

Comparisons of the efficacy of all the techniques used predict that since the ranges and standard deviations in all the measures are generally high, there is significant interindividual variability, so it is probably impossible to systematically resort to a reference value [12, 13]. It demonstrates the different errors in each of the measurements: in the case of the posterior condylar line, for example, lateral dysplasia makes its assessment difficult, or in the case of the surgical transepicondylar axis, when there are degenerative changes, joint diseases, or nonmetallic artifacts, neither the medial groove nor the lateral epicondylar prominence, especially the medial groove, can be identified.

Suter et al. [9] compared the clinical transepicondylar axis (cTEA) and the surgical transepicondylar axis (sTEA) and concluded that to assess the rotational alignment of the femoral component, the clinical TEA shows better statistical results

than the surgical TEA. Victor et al. [13] evaluated cTEA and sTEA in the new surgical techniques of navigated arthroplasty and concluded that although both present similar intraoperative localization difficulties, multiple errors have been recorded in navigated total knee arthroplasties for clinical TEA. They also describe that the highest variability values are those of the TEA and the lowest of the PCL. For this reason, this is considered one of the best anatomical references. Other studies add three-dimensional information, including as reference axes the femorotibial relationship in flexion and extension or the situation of the joint line about the femora-patellar joint.

The findings from this investigation and the literature consulted show that 3D-CT provides the most accurate determination of total knee arthroplasty (TKA) component rotation. The reviewed studies are inconclusive regarding normative values on TKA component rotation because the cutoff points still need clarification. Given this, to reduce variability, the joint decision was made to take as reference points for measuring the rotation angles of the femoral component of the clinical epicondylar axis concerning the posterior condylar line using a 2D tomographic study. In contrast, for the tibial component, a consensus was reached to take as reference the rear edge of the tibial component about the geometric center and the tibial tubercle in 16-slice 3D CT. However, the equipment was subsequently renewed, which allowed us to use a 128-slice tomograph that reduces the artifact of the prosthetic components, thus considerably improving the identification of the anatomical references described above for their measurement.

It is emphasized that care must be taken when concluding CT rotation measurements. If rotational errors are suspected, after ruling out other causes of malfunction after TKA, 3D-CT should preferably be used.

Future research should focus on the regular rotation ranges of components after TKA and their anatomical landmarks.

## Conclusions

The use of computerized axial tomography as a tool for measuring angles of rotation of prosthetic components presents a very reliable index for identifying the degree of effective functional process of the limb. It, therefore, makes it possible to predict the percentage of revision or failure. Even though rotational angles of the femoral and tibial components were found to be outside the accepted ranges, no complications related to mechanical prosthetic loosening were reported in the short or medium term, which questions the tolerable limit to maintain adequate biomechanics. In addition, the functionality of the knee.

Similarly, good results were obtained regarding clinical and functional assessment measured by the Knee Society Scale in the immediate and late postoperative periods. This supports the low rate of revisions after arthroplasty and predicts an adequate correlation of the surgical technique.

The variability of these imaging parameters could be associated with the lack of a precise anatomical reference, especially for calculating the rotation of the tibial component, which makes it possible to standardize its measurement and reduces interobserver variability.

It is suggested to continue a medium- and long-term follow-up of the operated patients to determine signs of loosening and the percentage of patients requiring revision arthroplasty.

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## Statements

### Ethics committee approval and consent to participate

The ethics committee of the Alcívar Hospital approved the study.

### Publication Consent

The authors have written permission to publish the images presented in this study by the patients.

### Conflicts of interest

The authors declare they have no conflicts of interest.

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