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Original article

Is the preoperative leg axis similar in radiographic and computer measurements in frontal deformities?

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ABSTRACT

Introduction: A prerequisite for ensuring a good clinical and functional outcome in total knee arthroplasty is knowing the preoperative leg alignment. This alignment is obtained using a long radiograph including the hip and knee, or a computer algorithm derived from palpation of landmarks and mapping of bone structures. It has been recommended to omit the preoperative radiograph if technology-assisted systems are to be used, but doubts exist regarding the similarity between both measurements, especially in frontal varus or valgus deformities.
Material and methods: The preoperative leg alignment was analyzed in 123 patients scheduled for total knee arthroplasty. Thirty-eight had a preoperative valgus axis radiographically, and 85 had a varus axis. A computer program was used to perform the radiographic measurement of the mechanical axis of the leg, and at the start of the procedure, this same measurement was verified with a technology-assisted navigation system (TAS).
Results: In the valgus group, the mean preoperative radiographic axis was 169.1º (SD 5.06), while the axis measured using the TAS was 171.9º (SD 3.96) (p=0.009). In the varus group, the mean radiographic axis was 191.9º (SD 5.86), and the axis measured using the TAS was 189.7º (SD 4.84) (p=0.008). The Pearson correlation coefficient comparing both measurements was 0.650 in the varus group and 0.237 in the valgus group (p=0.151).
Conclusions: The discrepancy between limb axis measurements obtained radiographically and those obtained with technological aids does not preclude the use of radiography in the preoperative evaluation of total knee arthroplasties.

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¿El eje de la pierna preoperatoria es similar en las mediciones radiográficas y computacionales en las deformidades frontales?

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RESUMEN

Introducción: Una condición imprescindible para asegurar un buen resultado clínico y funcional de la artroplastia total de rodilla es conocer la alineación previa de la pierna. Para obtener esta alineación se utiliza la radiografía larga incluyendo cadera y rodilla o un algoritmo informático conseguido a partir de palpación de referencias y mapeo de estructuras óseas. Se ha recomendado obviar la radiografía previa si se va a utilizar sistemas asistidos con tecnología, pero existen dudas en cuanto a la similitud entre ambas mediciones, sobre todo en deformidades frontales en varo o valgo

Material y métodos: Se ha analizado la alineación preoperatoria de la pierna en 123 pacientes que iban a ser intervenidos para implantar una artroplastia total de rodilla. Treinta y ocho tenían radiográficamente un eje preoperatorio en valgo y 85 en varo. Se utilizó un programa informático para realizar la medición radiográfica del eje mecánico de la pierna y al iniciar el procedimiento se comprobó esta misma medición con un sistema de navegación con ayuda tecnológica (TAS).

Resultados: En el grupo de valgo el eje preoperatorio radiográfico medio fue de 169.1º (SD 5.06) y el que se mostró mediante el TAS fue de 171.9º (SD 3.96) (p=0.009). En el grupo de varo la media radiográfica fue de 191.9º (SD 5.86) y el mostrado por la TAS de 189.7º (SD 4.84) (p=0.008). El coeficiente de correlación de Pearson comparando ambas mediciones fue de 0.650 en el grupo de varos y 0.237 en el de valgos (p=0.151).

Conclusiones: La discordancia entre la medición del eje de la extremidad obtenida radiográficamente o con sistemas de ayuda tecnológica no permite obviar la realización de una radiografía en el estudio preoperatorio de las artroplastias totales de rodilla.

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1. INTRODUCTION

Incorrect placement of the total knee arthroplasty (TKA) can cause an alteration in the limb axis and ultimately lead to failure of the procedure. To avoid such errors and to improve manual instrumentation during the implantation of TKA, technological-assisted systems (TAS) have been recommended. Although there is debate regarding the long-term clinical and functional improvement provided by TAS, the literature consistently indicates that these systems improve component alignment and final TKA axis, and they have thus been recommended in recent years [1].

To ensure proper positioning of the TKA, it is essential to know the preoperative limb alignment through a full-length limb radiograph or a computed tomography (CT) scan. At the beginning of the surgical procedure, this axis is usually confirmed using TAS, which then guides the surgeon on the optimal location and direction of femoral and tibial osteotomies to ensure correct implant positioning. Although the literature has shown concordance between the preoperative alignment of the leg obtained by radiograph and the measurement using TAS, it is not known whether this relationship holds in cases with frontal deformities, precisely the scenarios in which these systems are most often recommended [2]. If this concordance does not exist, the usefulness of TAS in achieving proper final leg alignment would be questionable, as its benefits could not be confirmed due to inaccurate or inconsistent measurements.

Our first objective is to compare the preoperative leg alignment measured radiographically and with TAS and to evaluate the agreement between the two in a series of cases with frontal deformities. The second objective is to determine whether varus or valgus deformity influences the relationship between both measurements.

2. MATERIAL AND METHODS

This was a prospective, non-randomized study. The series included 123 patients who underwent implantation of the same model of TKA using the same technological-assisted

system (TAS), and who radiographically showed a frontal deformity in varus or valgus greater than 3º. Cases were selected after a preoperative full-length radiograph including the hip, knee, and ankle, with the projection centred on the knee (PreRx), and with a metallic reference marker of known diameter. Using specific software (Impax 6.3.1.2813, Agfa Healthcare N.U. Montsel, Belgium), the images were sent to the surgical planning software (Agfa Orthopaedics Tools version 2.06). This tool was used to first calculate the mechanical axes of the femur and tibia, and then the mechanical axis of the entire leg.

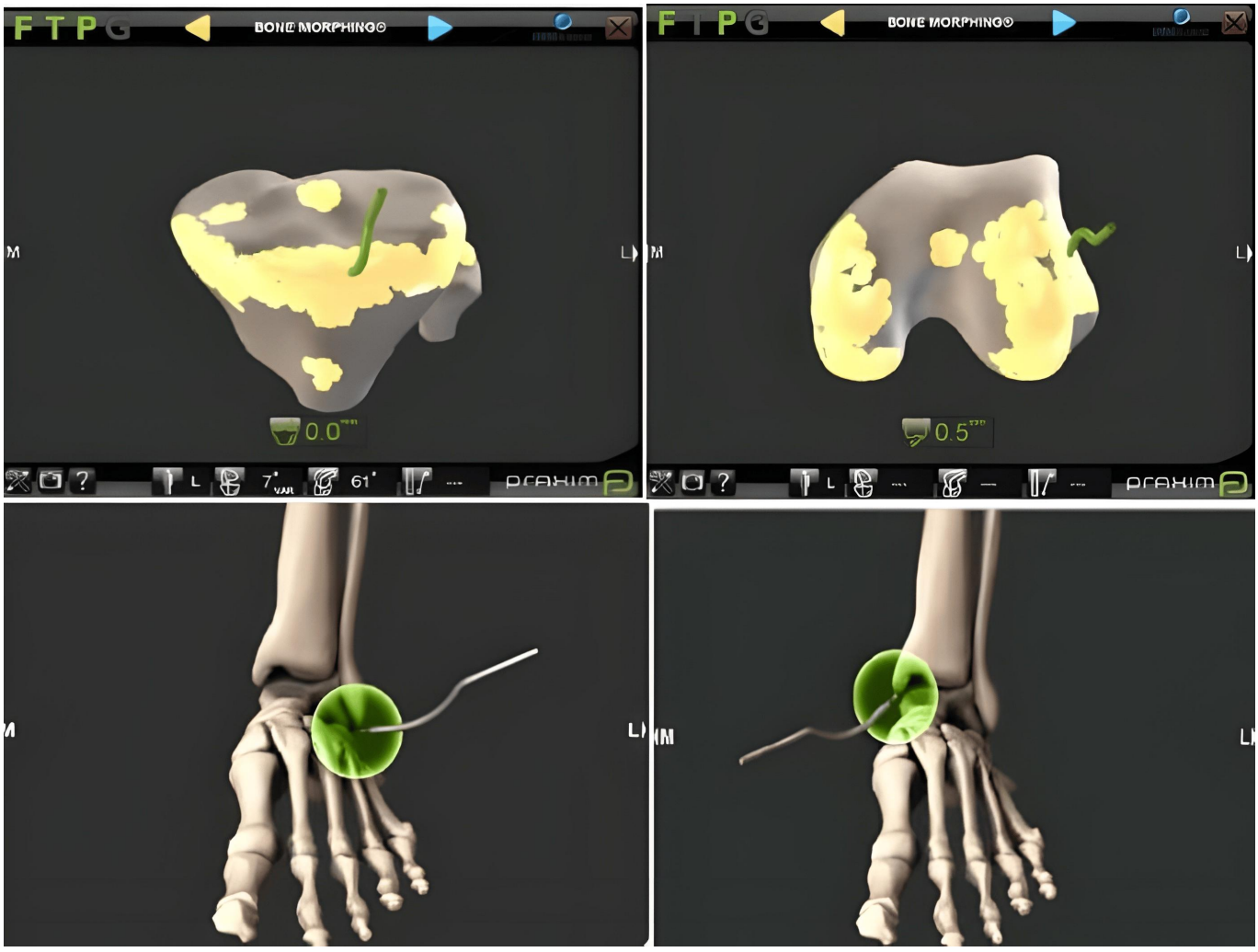

Figure 1: *Mapping on the tibial plateau and femoral condyles. Reference points taken at the ankle.*

In all cases, the same closed, image-free TAS was used (OMNIBotics system, Corin Group, Cirencester, UK). First, transmitters were placed on the femur and tibia, and after collecting specific bony landmarks and mapping the femoral and tibial surfaces (Figure 1), the TAS used an algorithm to deduce the mechanical axis of the limb (PreTA), which was then compared to the radiological measurement (Figure 2). Varus angulation was considered positive (≥183º), and valgus angulation was considered negative (≤177º).

Two of the authors, who had extensive experience using both techniques, performed both the radiographic and TAS measurements. Specific informed consent was obtained from all study participants. The Regional Ethics Committee (PI12/01098) approved the study.

2.1. STATISTICAL ANALYSIS

Quantitative variables were expressed as mean ± standard deviation (SD). Categorical variables were expressed as counts and percentages (n [%]). Comparisons between numerical variables were analyzed using Student's t-test. Pearson's test was also used to determine the correlation coefficient between the PreRx (radiographic measurement) and PreTA variables. A p-value of <0.05 was considered statistically significant. The statistical analysis was performed using Stata software, version 16 (StataCorp LLC,

Texas, USA).

Figure 2: *Limb axis on X-ray and with TAS.*

3. RESULTS

Of the 123 patients, 38 had a preoperative valgus axis on radiograph and 85 had a varus axis. The mean age of the series was 71.4 years (SD 9.36), with more than half of the patients being over 70 years old. No significant age differences were found between the valgus and varus groups. The mean BMI of the series was 30.7 (SD 6.83), also without statistically significant differences between groups. There was a predominance of female patients in the valgus group, with a statistically significant difference.

Within the valgus group, most cases (34 out of 38) had values between 161º and 175º. In the varus group, the most frequent cases (69 out of 85) were between 186º and 200º (Figure 3). The overall mean preoperative radiographic axis (PreRx) was 184.86º (SD 11.99), while the mean TAS measurement (PreTA) was 184.2º (SD 9.45).

In the valgus group, the mean PreRx was 169.1º (SD 5.06) and the mean PreTA was 171.9º (SD 3.96), with a statistically significant difference ($p = 0.009$) (95% CI 0.711 to 4.869) (Figure 4). In the varus group, the mean PreRx was 191.9º (SD 5.86), and the mean PreTA was 189.7º (SD 4.84), also with a statistically significant difference ($p = 0.008$) (95% CI -3.829 to-0.571) (Figure 5). The Pearson correlation coefficient between PreRx and PreTA throughout the series was 0.898. In the varus group, it was 0.650 and in the valgus group, it was 0.237 ($p = 0.151$).

4. DISCUSSION

In our study, we observed significant differences between the preoperative leg axis measurements obtained via radiography and those obtained using TAS in both the valgus and varus deformity groups. While the combined analysis of both groups showed good overall correlation between radiographic and TAS measurements, this correlation decreased markedly when analyzing the groups separately. In the valgus group, a weak but direct linear correlation was observed.

Although TKA has been confirmed as a procedure that offers good clinical and functional outcomes, between 15% and 25% of patients report dissatisfaction after surgery [3]. Many factors may contribute to this, including incorrect limb alignment after TKA, which can even lead to failure of the procedure [4]. To avoid this, it is essential to first obtain an accurate measurement of the preoperative mechanical axis of the limb in the frontal plane, which is critical for planning, performing, and evaluating the TKA. Various tools—such as long-leg radiographs, computed tomography, MRI, and TAS—can be used to determine true leg alignment [5], though long radiographs and TAS are most used.

Several strategies have been recommended to improve alignment during TKA surgery [6]. The use of TAS has been associated with a greater quality-adjusted life expectancy, lower costs [7], and a reduced need for revision surgeries [8]. While there is some controversy in the literature regarding whether this technology leads to better clinical and functional outcomes, it is generally accepted that TAS is helpful in achieving better implant positioning with respect to the limb axis [9]. These systems use the preoperative image as a reference and guide the necessary steps for proper implantation in terms of size, spatial orientation, and ligament balance.

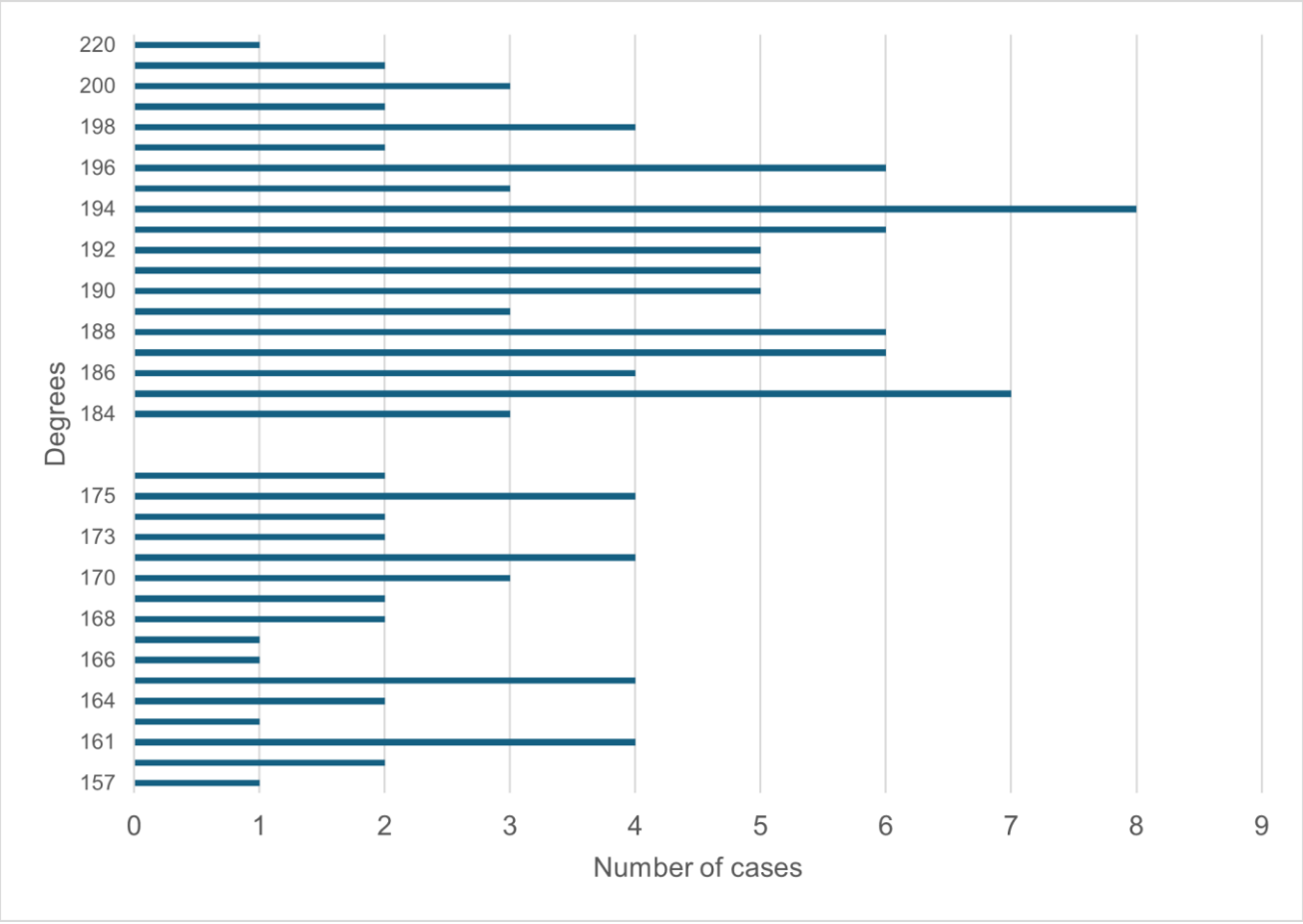

Figure 3: *Preoperative leg axis in the valgus group (≤ 177º) and in the varus group (≥ 184º).*

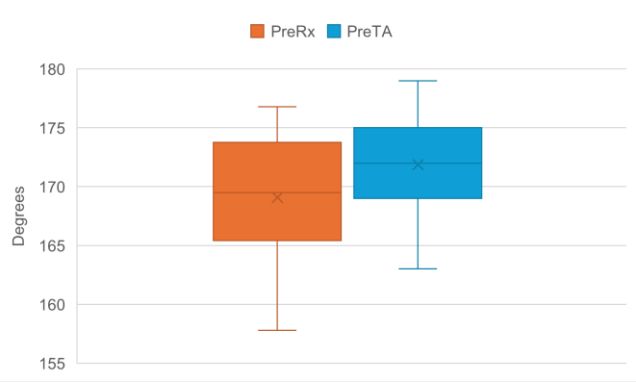

Figure 4: *Differences between PreRx and PreTA in the valgus group.*

Recent studies have analyzed the concordance between CT and TAS in measuring the sagittal axis of the leg, with poor agreement reported [10]. However, high correlation has been found between preoperative frontal radiographic measurements and TAS readings in general patient series, without separating out those with frontal deformities. Some have even recommended eliminating preoperative radiographs when TAS is used for TKA implantation [11]. While some authors report good agreement between both systems [12], they also find worse results when frontal deformities are present. The discrepancy between preoperative radiographs and navigation measurements increases with the degree of limb deformity and may reach up to 12º in some studies [13], which indicate that radiographic measurements tend to show greater preoperative deformity than the corresponding TAS measurements.

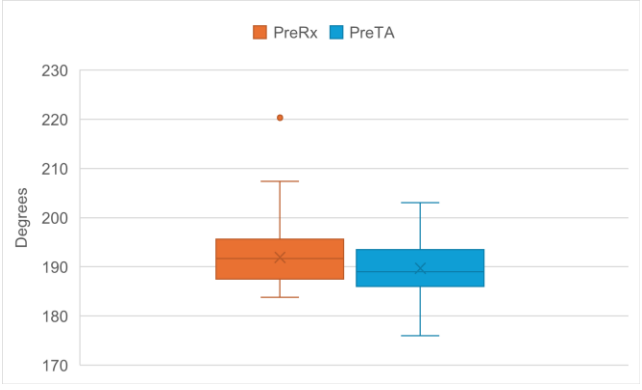

Figure 5: *Differences between PreRx and PreTA in the varus group.*

Nevertheless, no studies have specifically focused on the relationship between both measurement systems when analyzing only patients with varus or valgus deformities, precisely the scenarios in which computer-assisted systems are most indicated. Our work focused on these cases, and we did not find similar studies in the literature reviewed.

The disagreement between radiographic and TAS measurements that we observed may be due to errors in limb positioning during the long radiograph [14], or to inaccuracies in palpating bony landmarks during TAS use. Both situations may be more common in cases with frontal deformities, which would support our findings. While radiographic axis measurement is based on clearly visible, well-defined landmarks, TAS constructs its image and axis from an algorithm that relies on manually palpated bony landmarks and the mapping of specific structures. Computer navigation serves as the foundational step in all technology-assisted TKA workflows, making it crucial to understand how errors may be introduced during digitization of bony landmarks. Although TAS uses advanced technology, the final measurement still depends on personal decisions and may ultimately produce inaccurate results [15, 16]. The recent identification of common error sources, particularly during registration of critical areas such as the centre of the femoral and tibial surfaces, supports this possibility [17]. If the limb axis shown by radiograph and TAS do not match, the surgical technique guided by TAS may result in suboptimal postoperative alignment.

Our work has some limitations. First, the sample is asymmetrical, with a greater number of varus than valgus cases. This disparity is common in the literature on knee arthroplasty, as varus deformity is more frequent than valgus, especially when analyzing extreme degrees. We used a single navigation system and a single arthroplasty model. We do not know if other models and systems might alter our results. Our study only provides findings regarding radiographic or navigation-guided alignment. We do not know if the difference between the two methods of measuring the leg axis will affect clinical outcomes

The discrepancy found between these two measurements in our study does not support omitting the preoperative leg radiograph prior to TKA placement. The alignment shown by TAS is subject to error in patients with frontal deformities and must be interpreted cautiously, as the most critical impact of landmark errors is on final implant positioning.

5. ACKNOWLEDGEMENTS

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6. CONFLICT OF INTERESTS

The authors have no conflict of interest to declare. The authors declared that this study has received no financial support.

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