Original article

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How common is extra-articular knee deformity? How to achieve a «safe zone» alignment total knee arthroplasty in patients with extra-articular deformity

¿Qué tan común es la deformidad extraarticular de rodilla? ¿Cómo lograr una artroplastia total de rodilla con alineación de «zona segura» en pacientes con deformidad extraarticular?

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ABSTRACT. The need for total knee arthroplasty is increasing considerably and one of the goals is to achieve post-surgical coronal alignment. Robotic surgical assistance achieves a functional alignment, which is a hip-knee-ankle angle of 0º. However, it is not possible to provide robotic assisted surgery to all our patients so we must include the full-length hip-to-ankle AP weight-bearing radiograph in preoperative planning to obtain a «safe zone» alignment, which is a post-surgical hip-knee-ankle Angle of 0 ± 3º. How can we achieve a «safe zone» alignment total knee arthroplasty in patients with extra-articular deformity?

Keywords: mechanical alignment, kinematic alignment, «safe zone» alignment, functional alignment, extra-articular deformity, intra-articular correction.

RESUMEN. La necesidad de artroplastia total de rodilla está aumentando considerablemente y uno de los objetivos es lograr la alineación coronal postquirúrgica. La asistencia quirúrgica robótica consigue una alineación funcional, que es un ángulo cadera-rodilla-tobillo de 0º. Sin embargo, no es posible ofrecer cirugía asistida por robot a todos nuestros pacientes, por lo que debemos incluir la radiografía AP de soporte de peso de cadera a tobillo de cuerpo entero en la planificación preoperatoria para obtener una alineación de «zona segura», que es un ángulo postquirúrgico cadera-rodilla-tobillo de 0 ± 3º. ¿Cómo podemos conseguir una artroplastia total de rodilla con alineación de «zona segura» en pacientes con deformidad extraarticular?

Palabras clave: alineación mecánica, alineación cinemática, alineación «zona segura», alineación funcional, deformidad extraarticular, corrección intraarticular.

Introduction

The need for total knee arthroplasty (TKA) is increasing. In the United Kingdom more than 100,000 TKA are performed each year and 700,000 in the United States.[1] We consider TKA to be successful if we relieve the patient's pain, achieve complete and stable mobility with adequate post-surgical alignment, and improve long-term function.[2]

To achieve this post-surgical alignment it is necessary to remember all of the measurements to be included in

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preoperative planning.[2,3,4,5,6,7,8,9,10,11] Initially, we must identify the center of the femoral head, the joint center of the distal femur (JCDF),[12,13] the joint center of the proximal tibia, and the joint center of the ankle *(Figure 1)*;[14] which will allow us to draw the following axes: femoral anatomical axis (FAA), tibial anatomical axis, femoral mechanical axis (FMA), tibial mechanical axis, distal femoral osteotomy (DFO) line and tibial joint line *(Figure 2)*. The line to connect the center of the femoral head to the joint center of the ankle is named the load axis, mechanical axis, or Maquet line.[15,16,17]

To make a distal femoral osteotomy completely perpendicular to the femoral mechanical axis (a DFO with 90º to FMA) we calculate the angle between FMA and FAA *(Figure 2)*.[2,7] But if we have an extra-articular deformity (EAD), meaning a femoral or tibial angulation located at 5 cm proximal or distal to the knee joint line,[2,18,19] outcomes are going to be different and the likelihood of achieving the correct post-surgical alignment will be decreased. The problem is more critical on the femoral side because the endo-medullar guide can change its position by hitting the cortical bone and thereby changing the DFO and the final alignment. On the tibial side the extramedullary guide allows us to make any correction that is needed.[18,18,20,21] You can achieve a successful intra-articular correction (IAC) if the deformity does not exceed the coronal plane by 20º at the femur or 30º at the tibia.[2,18,22]

Figure 2:

Preoperative planning axes. **A)** Femoral anatomical axis, **B)** tibial anatomical axis, **C)** femoral mechanical axis, **D)** tibial mechanical axis, **E)** distal femoral osteotomy (perpendicular line to femoral mechanical axis), **F)** tibial joint line (dotted line- In this case is not perpendicular to tibial mechanical axis).

Concepts of alignment *(Figure 3)*.

1. The classic alignment or mechanical alignment (MA) is when the femoral and tibial osteotomies are at 90º to the femoral mechanical axis and tibial mechanical axis. We can confirm this while the Maquet line passes through the prosthetic center (hip-knee-ankle angle [HKAA] of 0º).[2,3,4]
2. The kinematic alignment (KA) is a restoration of the pre-arthritic femoral joint line that adjusts the extension and flexion gaps by resecting the proximal tibia, but rotational configuration is guided by lateral tibial plateau.[23]
3. The inverse kinematic alignment (IKA) is the restoration of the pre-arthritic tibial joint line with an osteotomy between 84- 92º to a tibial mechanical axis which solves kinematic alignment laxity problems.[24,25,26,27,28]
4. The restricted kinematic alignment (RKA) resolves the KA medial load problem. It is a hybrid of mechanical alignment and kinematic alignment: a femoral osteotomy with 90-93º and a tibial osteotomy with 87-90º to achieve a «safe zone» alignment (SZA), meaning a postsurgical HKAA 0 ± 3º.[24,25,26,27,28]
5. The functional alignment (FA) is an objective of robotic assisted surgery, specifically to obtain an HKAA close to 0º. In this case, we remove the osteophytes, make distal femoral and proximal tibial thin osteotomies close to 90º relative to each femoral mechanical axis and tibial mechanical axis to finish with a soft tissue-friendly-release.[26,28]

Figure 1:

The preoperative planning begin to identify: **A)** center of femoral head, **B)** joint center of distal femur (midpoint of the femoral length at the height of the notch without considering osteophytes), **C)** joint center of proximal tibia (midpoint of the tibial length immediately distal to the articular surface without considering osteophytes), **D)** joint center of ankle (midpoint of tibiofibular length parallel and proximal to the line to connect the medial- lateral articular surfaces of talus).

Robotic assistance is yielding better outcomes, but in our country not every patient has access to this technology and in those cases the next best option is the SZA with excellent preoperative planning.[29]

Our objective is to demonstrate the prevalence of EAD in our patients and to share a simple method, which allows one to identify EAD and to achieve a «safe zone» alignment TKA in patients who have EAD without robotic assistance.

Material and methods

Observational study with non-probability sampling.

We evaluated 64 full-length hip-to-ankle AP weight-bearing radiographs from March 2020 to August 2021 in Querétaro, México. Selection criteria: A) Inclusion: complete preoperative radiograph. B) Exclusion: radiograph with no prosthetic surgery in the lower limb. C) Elimination: incomplete preoperative radiograph.

In addition to each positive case, we again looked for deformity with the LOFAC method to look for a different outcome.

Matsumoto method *(Figure 4)*.[30] This method requires a reference scale which will allow identification of four femoral points: A) the midpoint of the width at the height lesser trochanter, B) the midpoint of the width at a level 7.5 cm below the lesser trochanter, C) the midpoint of the width at a level 15 cm above the femoral joint surface, D) the midpoint of the width at a level 7.5 cm above the femoral joint line. Then measuring the angle between the line to connect points AB and the line to connect points CD. The angle should be 0º.

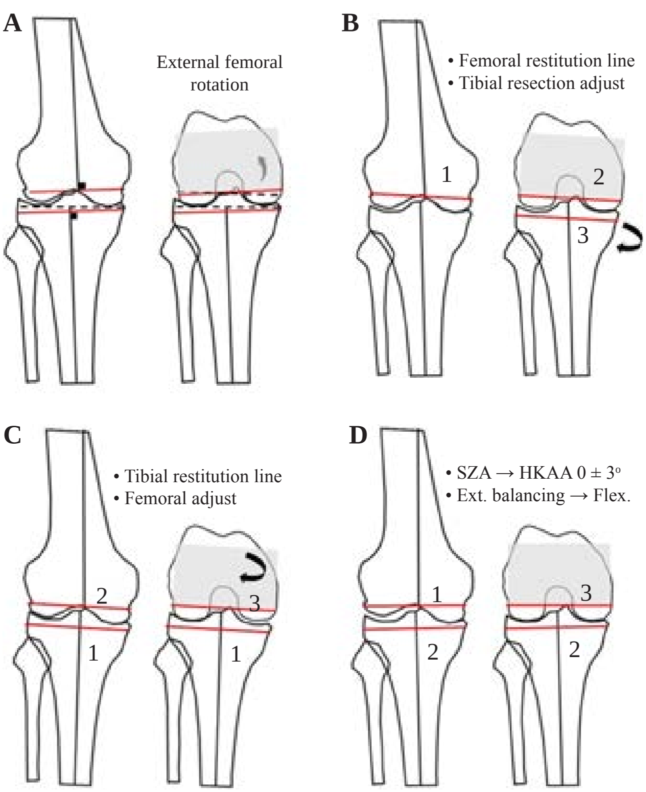

Figure 3: Alignment concepts. **A)** Mechanical alignment. **B)** Kinematic alignment. **C)** Inverse kinematic alignment. **D)** Restricted kinematic alignment. Red lines represent the osteotomies.
Numbers are reference points.
SZA = «safe zone» alignment. HKAA = hip-knee-ankle angle.

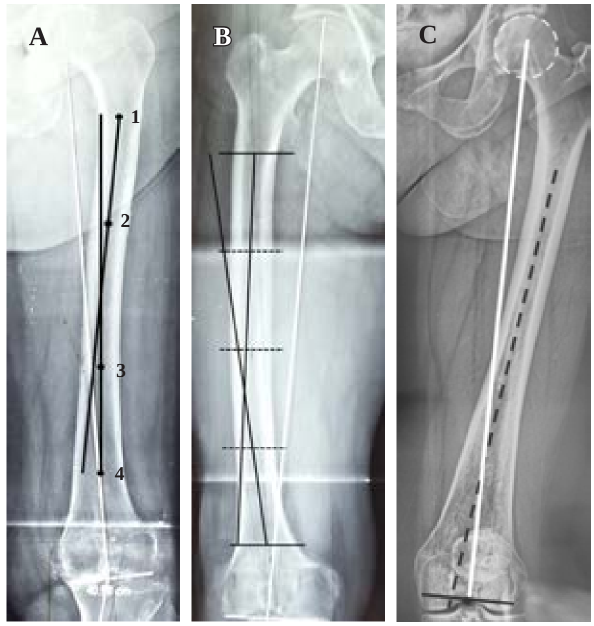

Figure 4: Methods to look for extra-articular deformity. **A)** Matsumoto method. **B)** Yau method. **C)** LOFAC method.
Numbers are reference points.

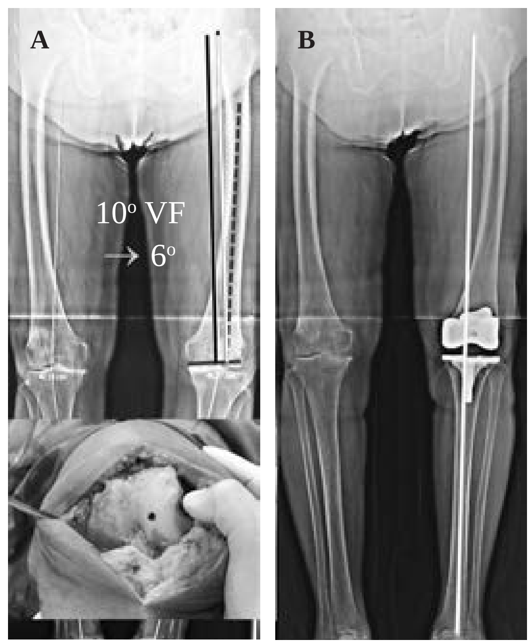

Figure 5: LOFAC method. **A)** Step 1 changes the femoral guide's entrance point and step 2 changes the osteotomy's valgus (in this case change to 6º). **B)** Postsurgical control with «safe zone» alignment.

Yau method *(Figure 4)*.[31] This is the suggested method when you do not have a scale reference in the image. The femoral diaphysis is first divided into four segments. Then the angle between lines that describes the endo-medullar canal of the proximal and distal segments is measured. The angle should be less than 2º.

LOFAC (looking for and correcting extra-articular femoral deformity) method. The method can be used with or without a reference scale. First, identify the femoral mechanical axis and then draw another perpendicular line that represents the DFO. Finally, draw a dotted line that represents the femoral endo-medullar guide without cortical bone contact. When the dotted line does not contact the JCDF EAD is present *(Figure 4)*. Once EAD is identified the first step to make an IAC is to localize the femoral guide's entrance point that corresponds to the intersection point between the dotted line and the DFO line. The last step is to calculate the osteotomy's valgus to preserve the planned DFO (perpendicular line to FMA), the angle of which is formed by the dotted line and another new line that is parallel to the FMA, but which must have contact with the femoral guide's entrance point *(Figure 5)*.

Results

We evaluated 64 full-length hip-to-ankle AP weight-bearing radiographs (128 lower limbs) of Mexican patients, but only 115 lower extremities met the inclusion criteria.

The morphologic classification was: 51.3% (59 lower limbs) in the varus knee, 31.3% (36 lower extremities) in neutral alignment, and 17.3% (20 lower extremities) in the valgus knee. The joint line was: varus in 46.9% (54 knees), neutral in 46% (53 knees), and inverse in 6.9% (8 knees).

Extra articular deformities were seen in 58% of the lower limbs (67 lower extremities). The Matsumoto method was used in 45 extremities (28 patients) and the Yau method was used in 22 knees (13 patients). The extremities with EAD were distributed: varus knee 55.2% (37 knees), neutral morphology 28.3% (19 knees), and valgus knee 16.4% (11 knees). Femoral deformity was observed in 70.2% of extremities with EAD and varus knee (26 of 37 knees), in 84.2% of extremities with EAD and neutral morphology (16 of 19 knees), and 54.5% of extremities with EAD and valgus knee (6 of 11 extremities) *(Figure 6)*.

We did a second review with the LOFAC method in the 67 extremities with EAD, with a favorable outcome in the same number of cases. There is no difference in identification of EAD between the methods suggested by the literature and the methods presented here. Therefore, it is not necessary to carry out a statistical test to confirm it.

Finally, we found that 83% of the lower limbs with TKA (5 to 6 knees) did not achieve SZA, because the DFO was incorrect in four cases and the proximal tibial osteotomy was incorrect in one case.

Discussion

Regarding morphology of the lower extremities, the varus knee was predominant, but there was no difference between a varus or neutral joint line.

Before performing a TKA we must pay attention to the basic principles and to identify factors that may affect the postsurgical outcome. Doing so will allow us to carry out optimal and individualized preoperative planning for each patient.

Generally, when discussing EAD we imagine extremities with previous injuries such as fractures that have required one or more surgeries. However, in this investigation we were able to observe that EAD is a common finding with a prevalence of 58, demonstrating that it can occur in most of the population. It was also shown that the method that we propose here is just as useful for identifying EAD as the Matsumoto and Yau methods since there is no difference in outcomes.

Without regard to morphology, the deformity was located at the femur in more than half of the knees with EAD that was studied.

Today's literature suggests that achieving post-surgical FA in our patients can improve outcomes. But, as can occur in any country that is adopting new technology, not all our patients will have access to robotic assisted surgery so preoperative planning that incorporates a full-length hip-to-ankle AP weight-bearing radiograph is the next best option.

Today, in some hospitals with a large number of TKAs the preoperative planning is done with a simple AP knee X-ray. The findings of this study demonstrate that performing a TKA without an X-ray of the lower extremities in a standing

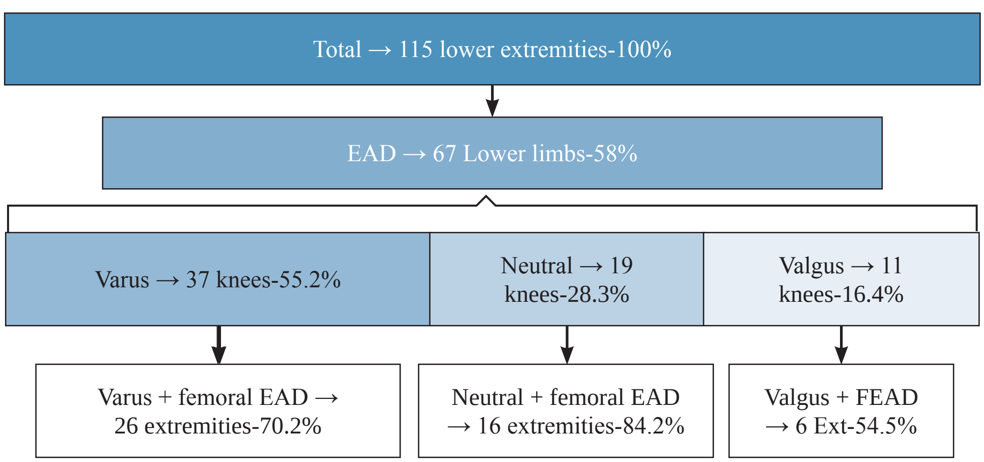

Figure 6:

Extra-articular deformity distribution. EAD = extra-articular deformity. FEAD = femoral extra-articular deformity.

position may account for some patients who are dissatisfied with the postoperative outcome. A weakness of this work is the sample size which, even though it is not small, could be larger and more representative.

Conclusion

EAD is common in the lower extremities and occurs in over half of the population. Additionally, the site where the deformity is most commonly located is in the femur. If we do not pay adequate attention to that area it is difficult to achieve a «safe zone» alignment, because in general the instruments for working on the femur are intramedullary devices.

We observed that the LOFAC method is equally effective in identifying EAD as other methods in the literature. In addition, the LOFAC method allows us to diagnose EAD at the same time as precisely calculating and making the IAC.

As in many areas of medicine changes in basic principles and concepts of prosthetic knee replacement have been necessary. For instance, a few years ago it was suggested that we consider a distal femoral osteotomy with 7º in case of a varus knee, 6º in case of a neutral morphology and 5º in case of the valgus knee. However, we now know that the distal femoral osteotomy is different in each patient, a fact that we bear in mind during preoperative planning, which should include a full-length hip-to-ankle AP weight-bearing radiograph.

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Consent for publication: we give the consent for publication in the Journal of Experimental Orthopaedics.

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