MENTORS IN ORTHOPEDICS

CONCEPT AND ADVANTAGES OF TROCHLEAR NAVIGATION FOR PROPER ROTATIONAL ALIGNMENT OF THE FEMUR COMPONENT IN TKA

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SUMMARY

Background: Precise rotational alignment of the femoral component in total knee arthroplasty (TKA) is critical for flexion gap symmetry and optimal patellofemoral tracking. Conventional methods, including visual identification of the transepicondylar axis or fixed 3° external rotation, often fail to account for significant individual anatomical variability in the posterior condylar angle.

Objective: This study evaluates the reliability and reproducibility of trochlear navigation, a computer-assisted technique that aligns the prosthetic component by superimposing it onto the native trochlear anatomy.

Key Points: A prospective study of 145 patients underwent TKA using a navigation system that utilizes bone morphing to create a 3D model. The technique aligns the prosthetic trochlea with the native trochlea across 30°, 60°, and 90° of flexion. Results demonstrated high concordance between navigated rotational values and preoperative CT measurements, with an average posterior condylar angle of 5° (range 0°–11°). Postoperative analysis showed 98.7% of patients had centered patellar tracking. Furthermore, 78% of cases achieved a flexion gap differential of less than 1 mm between medial and lateral compartments. The study also noted that achieving optimal alignment required a mean component lateralization of 2.3 mm in 76% of cases.

Conclusion: Trochlear navigation provides a precise method for determining femoral component rotation and mediolateral positioning. By prioritizing the restoration of native patellofemoral anatomy, the technique ensures stable kinematics and a balanced flexion gap, effectively addressing the limitations of empirical rotational targets and inconsistent anatomical landmarks.

KEYWORDS

Arthroplasty, Replacement, Knee; Surgery, Computer-Assisted; Femur; Rotation; Patellofemoral Joint

INTRODUCTION

Rotational alignment of the femoral component during total knee arthroplasty (TKA) is an important element of operative technique and remains a hot topic in the literature (1). It has serious implications on the clinical outcome because it influences balancing the flexion gap and the patellofemoral tracking (2-3). The literature reports several methods for achieving femur rotational alignment but none of them is sufficiently precise and the proper target remains still controversial (4). Intraoperative identification of the transepicondylar axis, visually or by navigation, is neither reliable nor reproducible (5-7). Empirical adjustment to 3° of external rotation does not take into account individual anatomical variability in the knees undergoing surgery. In fact, the angle formed by the posterior condylar line and the transepicondylar line (posterior condylar angle or alpha angle) tends to vary greatly between individuals (8-10). Nor have the gap balancing techniques that adjust rotation ‘automatically’ with a tensioning device been able to demonstrate their superiority.

The authors suggest trochlear navigation as an innovative technique to determine rotation of the femoral component. The rational of this technique is to consider the ideal rotation of the femoral component when the prosthetic trochlea is superimposed perfectly to the native trochlea on a patellofemoral Merchant’s view at 30, 60 and 90°. During planning the base of the prosthetic trochlea is thus aligned on Whiteside’s line, identified by trochlear morphing, which is perpendicular to the transepicondylar axis (11). In this way, the authors hope to promote centring of the prosthetic patellofemoral joint, thus prioritizing preservation of the extensor apparatus’s original kinematics.

This idea has been supported by a study that aimed to demonstrate that trochlear navigation is a reliable and reproducible method for adjusting rotation of the femoral component in relation to the transepicondylar axis which had been used as a reference point. Furthermore, it could be shown that adjusting rotation by this method has no adverse consequences for proper balancing the flexion gap.

MATERIALS AND METHOD

This was a prospective, non-randomized, two-centre study that included 145 consecutive patients who were recruited in two French centres by two surgeons. 66 patients were treated in centre A, the 79 others in centre B. There was no significant demographic difference between patients in the two centres and no patients were lost for follow-up. The average preoperative tibiofemoral axis was 175° and, furthermore, there was nothing noteworthy about the distribution of valgus and varus (Figure 1). The only exclusion criteria were large frontal deformities of more than 20° varus or valgus. All the patients joined the study in the year 2010 and all were seen again at 3 months and at 1 year postoperatively. Mean patient age was 71 years [53 to 88]. The sex ratio was 60% women. The right sides accounted for 54% of the knees undergoing surgery.

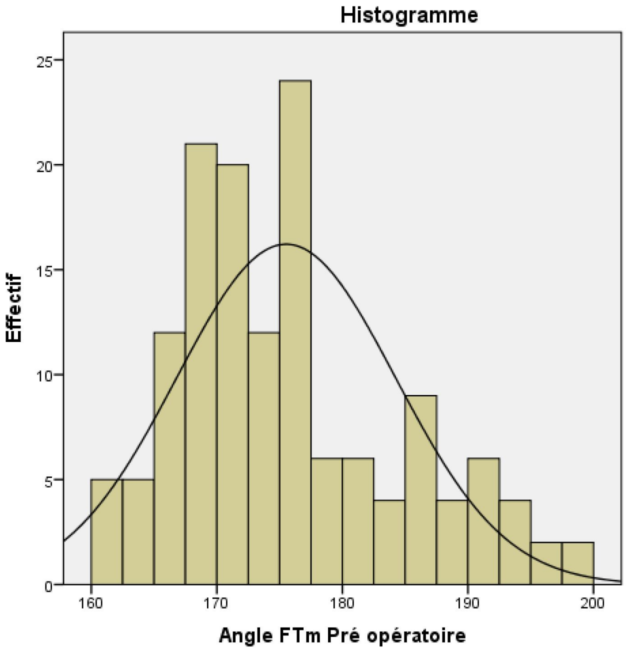


Figure 1: Distribution of preoperative mechanical tibiofemoral axes.

At their appointments, patients underwent preoperative and postoperative clinical and radiological examination, including a full leg CT scanogram and standard short weight-bearing films, as well as patellofemoral Merchant's views at 30 and 60°. There were 108 varus and 37 valgus knees with a mean mechanical tibiofemoral axis of 175° (range 160 to 200°)(Figure 1). 17% of the knees demonstrated patellofemoral arthritis (isolated or associated with tibiofemoral arthritis) with 11% of patella showing lateral subluxation but no case of dislocation could be observed.

All patients were reviewed at 3 months and at 1 year postoperatively using the IKS (International Knee Society) score. At the same appointment, patellofemoral Merchant's view films taken in 30 and 60° of flexion enabled analysis of patellar tracking (shifting and tilting). To assess the precision and reproducibility of the trochlear navigation concept, the results were assessed by comparison with the posterior condylar angle with CT scans (1 centre preop and one centre postop).

A standard medial parapatellar approach with lateral eversion of the patella was used in all cases of varus and valgus of less than 10°. A lateral retinaculum release was performed only when there was initial patella subluxation. A lateral approach without tibial tubercle osteotomy was performed for valgus knees with 10° or more. In both centres, the so-called 'cementless inset patella' technique was used. The polyethylene implant was placed in a milled area centred on the patellar ridge.

A highly congruent, mobile-bearing Score© arthroplasty (Amplitude©, France) was implanted, assisted by computer navigation (Amplivision®, Amplitude©, France). One of the characteristics of the Amplivision® navigation system is the intraoperative creation of a 3D bone model by using a special bone 'morphing' technique.

The navigation system's software thus enables a simulated prosthetic implant positioning on the shaped 3D bone model (Figure 2). For tibial component size and position planning, three views are available in in all three planes (Figure 3). For femoral component size and position planning, three views are available (AP and lateral), as well as patellofemoral Merchant's views at 30, 60 and 80°) to allow "trochlear navigation" (Figure 4 & 5).

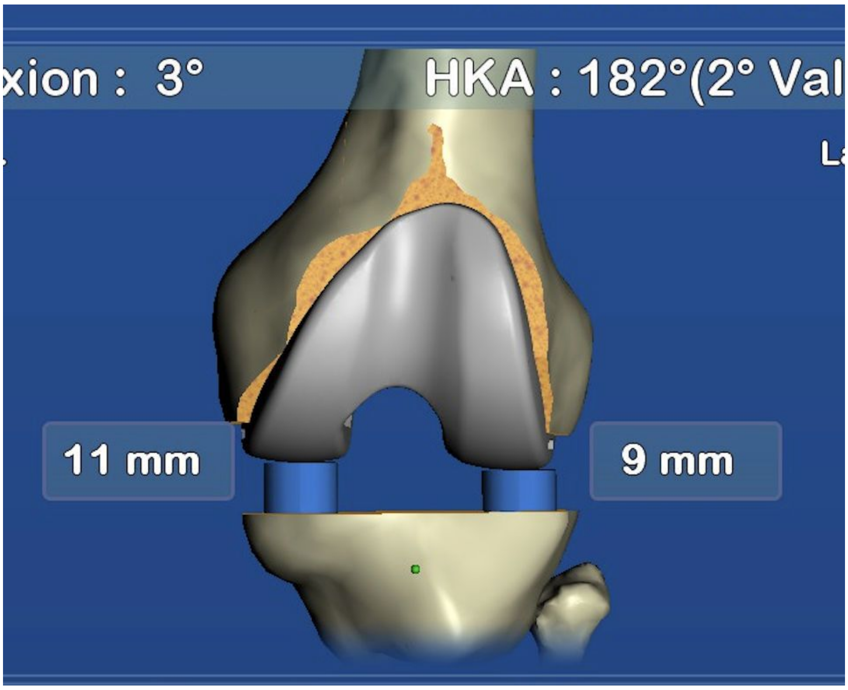


Figure 2: view of the shaped 3D model, simulated femoral component and simulated bone incisions.

Figure 3 : views available for tibial planning

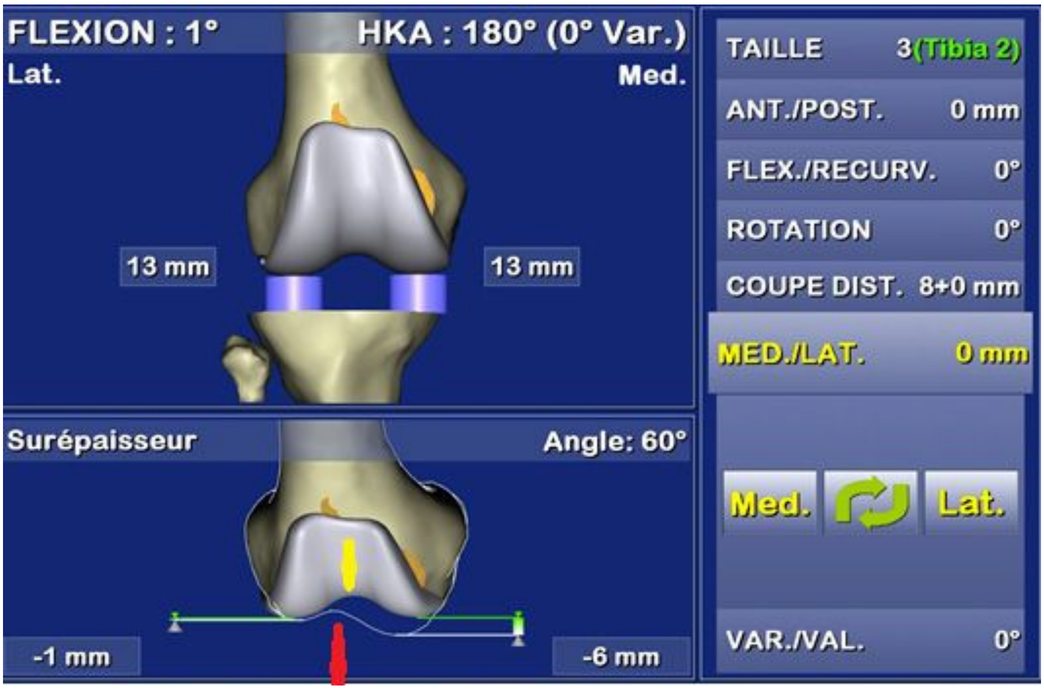


Figure 4: 60° view of the original trochlea (in white) and the eventual positioning of the femoral casing (in grey). For a rotation of 0° in relation to the posterior condylar plane. Note the lack of concordance between the eventual base of the prosthetic trochlea and Whiteside's line.

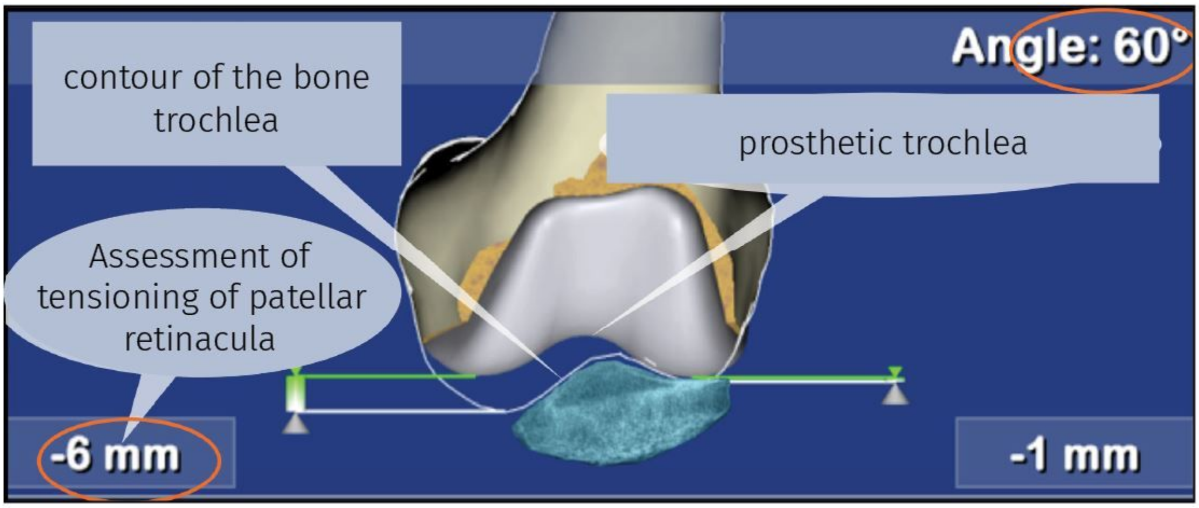
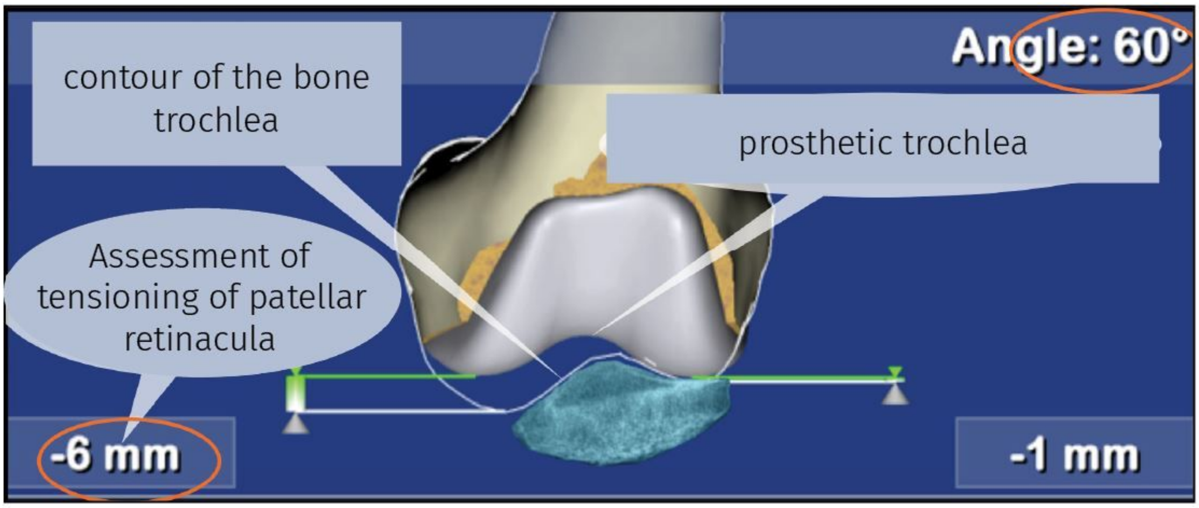


Figure 5: 60° patellofemoral Merchant's view. Visualization of the contours of the native trochlea and of the simulated prosthetic trochlea (ER 0°) enabling assessment of their relative positions, and indirectly, of the tensioning of the patellar retinacula. On this view, an artificial patella has been added for better understanding of the risk of external subluxation of the patella if the rotation and mediolateral position were not adjusted.

Operative strategy was identical in the two centres by using the navigation system. At the tibia, the 10 mm default bony resection from the healthy side was adapted for preoperative flexion/recurvatum deformtiy, patellar height and effect of the extension /flexion gap on the height of the joint space. The posterior tibia slope, assessed on the lateral view, was preserved within 6°, to minimize the risk of posterior component loosening. The tibial component was aligned perpendicular to the tibia's mechanical axis (varus/valgus = 0°) in neutral rotation (0°) parallel to Akagi's line.

At the femur, the aim was to place the femoral component according to the soft tissue frame, preserving as much as possible the femur's original anatomy and tibiofemoral kinematics. By this technique only cases of fixed varus with flexion contracture and large, non-reducible valgus deformities required ligament release. The size of the simulated femoral component was chosen to optimize its mediolateral and anteroposterior dimensions. The AP view allowed to rule out any mediolateral overhang of the component in relation to the simulated bone cuts. The lateral view, allowed modifying the degree of flexion/extension of the femoral component to preserve posterior offset. Furthermore any anterior notching can be avoided.

For the distal femur cut a neutral mechanical tibiofemoral axis (HKA) of 180° was the target. Rotational alignment and mediolateral positioning of the femoral component was systematically determined by using the so-called ‘trochlear navigation’ technique. The concept rests on “bone morphing” by superimposing the prosthetic trochlea and the native bone trochlea on the patellofemoral Merchant’s view at 30, 60 and 90° (Figure 5).



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By default, the alignment of the femoral component is parallel to the posterior condylar line (ER = 0°) and the mediolateral position is centred medio-lateral on the distal femoral incision. From this default starting point, the surgeon can:

- assess the position of the prosthetic trochlea in relation to the native bone trochlea, and indirectly, the tensioning of the patellar retinacula (Figure 5).

- modify the mediolateral and rotational position of the simulated femoral component in order to ‘bring’ the prosthetic trochlea into the place previously occupied by the native trochlea (Figures 6 & 7).

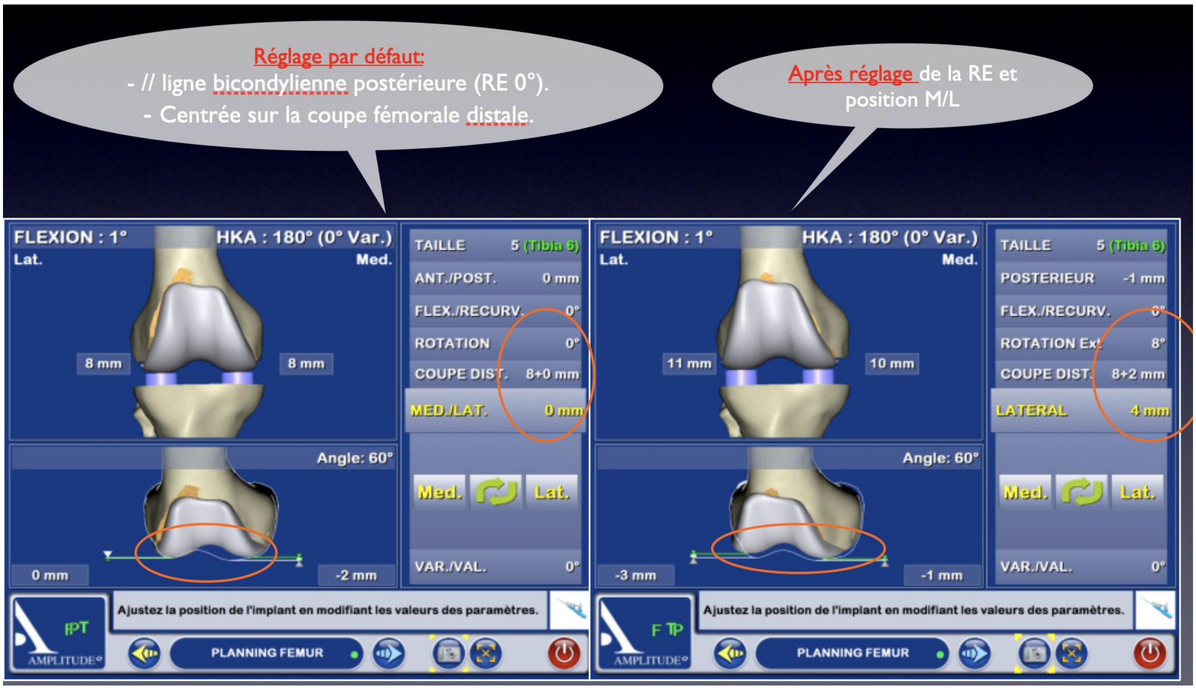

Figure 6: 60° view of the original trochlea (in white) and the eventual positioning of the femoral casing (in grey). For an external rotation of 8° in relation to the posterior condylar plane.

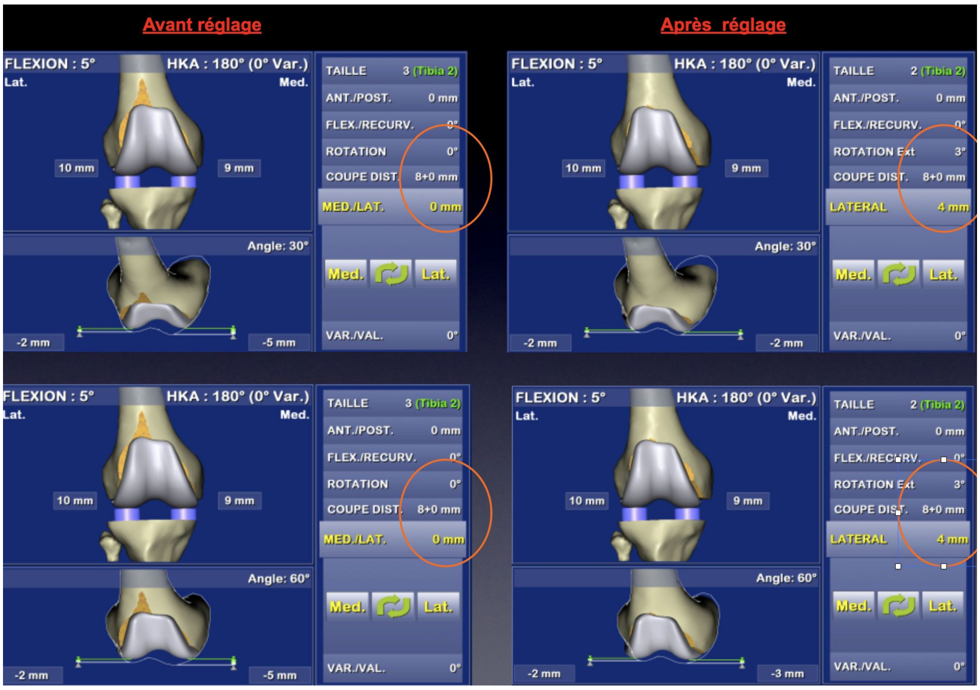

Figure 7: Example of trochlear navigation at 30 and 60° (before and after adjustment of rotation and mediolateral position). In this case, adjustment required 4 mm lateralization and 3° rotation.

The goal is to centre the prosthetic trochlea indirectly below the patella, to balance the the patellar retinacula and the extensor mechanism to preserve the original patellofemoral kinematics.

The flexion gap was assessed, after adjusting for rotation, by measuring the medial and lateral tibiofemoral space during forced varus and valgus stress with the knee at 90° and the patella reduced (Figure 8). In one centre, the CT measurement of the posterior condylar angle was performed preoperatively. At the time of operation, the surgeon was blinded to these result (Figure 9). All of the digital data were stored in the navigation system and then combined with the clinical data in a spreadsheet (Microsoft Excel©). The statistics were handled by SPSS© software (IBM SPSS Analysis, IBM, Armonk, New York, USA).

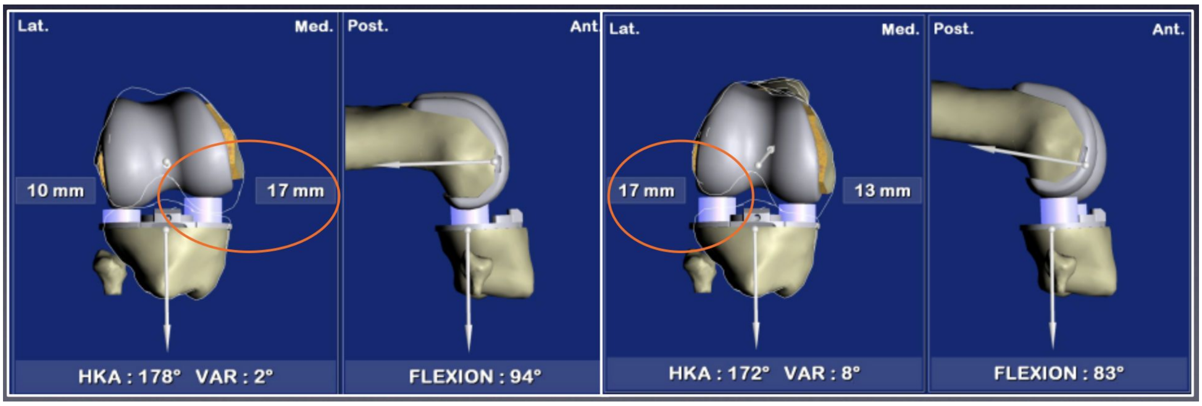

Figure 8: Measurement of the tibiofemoral space in forced varus and valgus, using the Amplivision navigation system

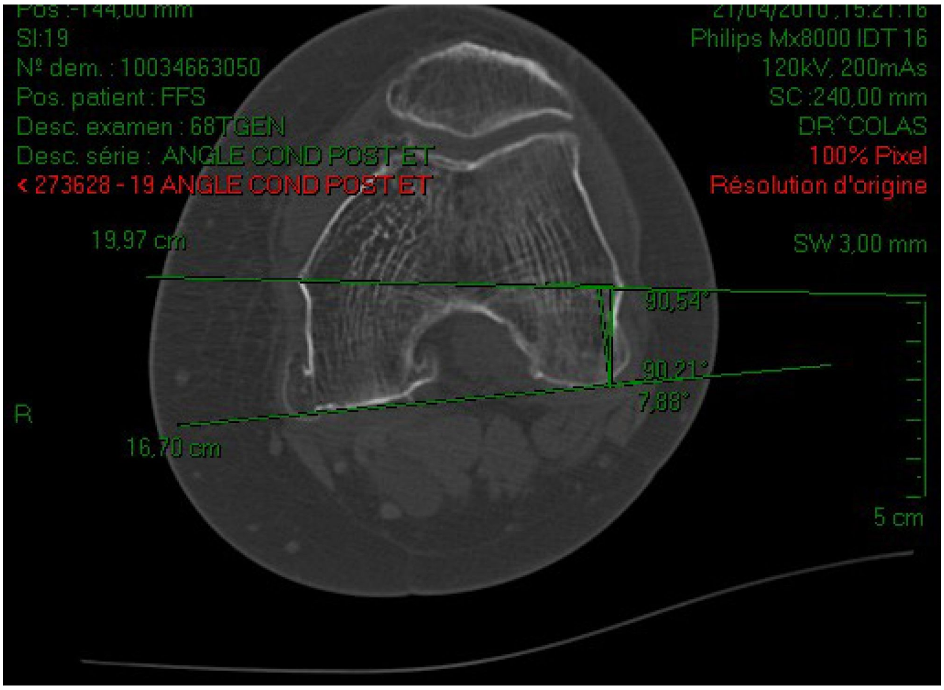

Figure 9: Preoperative CT of a knee to be replaced, calculating the angle between the posterior condylar plane and the axis that passes through the two epicondyles. Here it measures 8°.

RESULTS

Patellofemoral tracking

2 of the 145 patients (1.3%) presented with a patellar shift of more than 3 mm. Both patients presented preoperatively with lateral subluxation of the patella. 3 patients (2 %) presented with a patellar tilt of more than 10°. All other knees –demonstrated a perfectly centred patella (Figure 10).

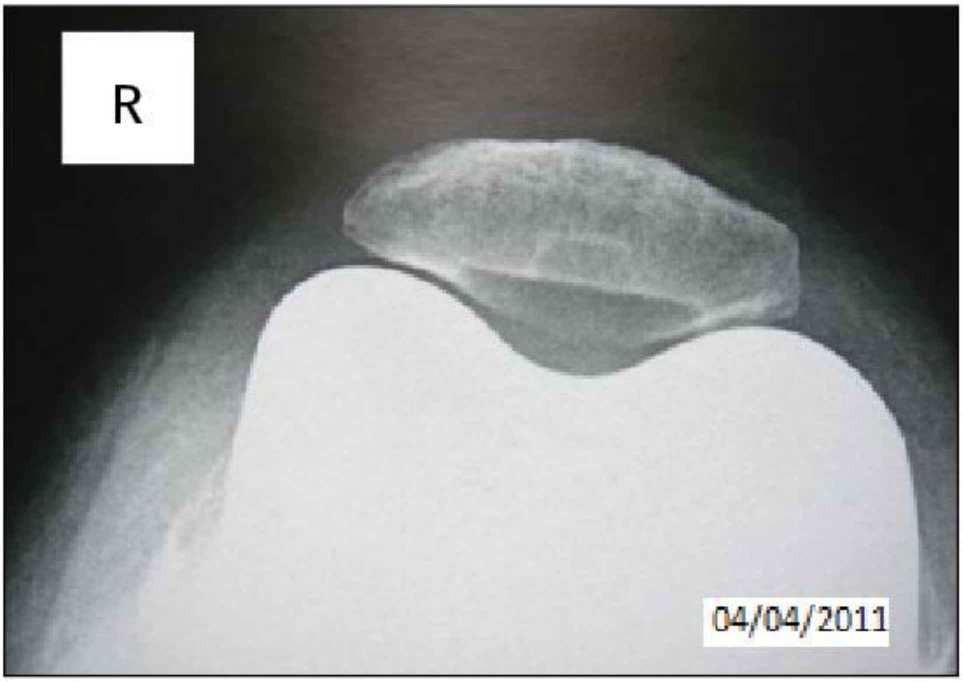

Figure 10: Patellofemoral Merchant's view at 30° 1 year postoperatively, showing centring of the native patellar bone and prosthesis.

Rotational alignment of the femur

Data gained with the navigation system compared to the CT scan are summarized in Table 1. The difference between the two average values is 1.5°. Note the absence of negative angles (= internal rotation), with both the navigation system and computed tomography. Figure 11 demonstrates the correlation between the values from the two methods. The difference observed between the two centres (averages of 4.3° and 5°) is not significant (Figure 12). Furthermore, a non-parametric Wilcoxon test, based on the hypothesis that the median of the differences between the angle produced by the CT scanner and the angle produced by the navigation system is equal to 0, is significant ($p<0,01$). This confirms good concordance between the angles produced by the two methods.

	Minimum	Maximum	Moyenne	Ecart type
Rotation Scanner	0	11	6,5°	2,32
Rotation Navigateur	0	9	5°	1,89

Table 1: Average values and distribution of the angle between the posterior condylar plane and the condylar axis.

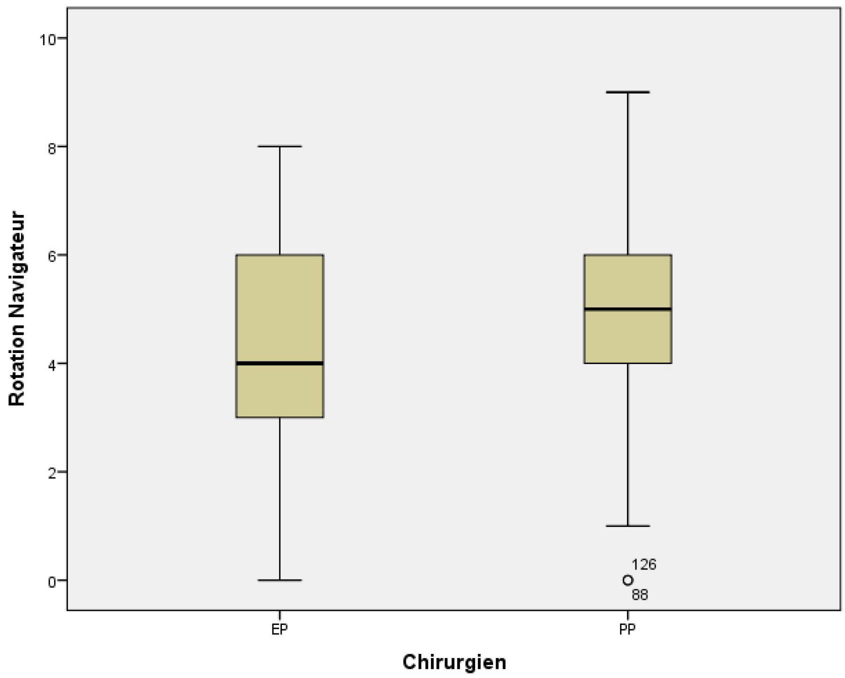

Figure 12: Comparison of the distributions of the values for angular divergence between the posterior condylar plane and the condylar axis for each of the operators, in centres A and B respectively.

Medio-lateral positioning

The mediolateral position of the femoral component, initially centred by the navigation system on the distal femoral cut, was modified in 76% of cases by lateralization of the component (no medialization). The average value for this lateralization was 2.3 mm [0; 5].

Flexion gap balancing

Figure 8 demonstrates that this innovative technique enables a balanced flexion gap. In this series, balancing in 90° of flexion is satisfactory since the differential between the lateral and medial tibiofemoral space was never greater than 2 mm. In 78% of cases, it was even below 1 mm.

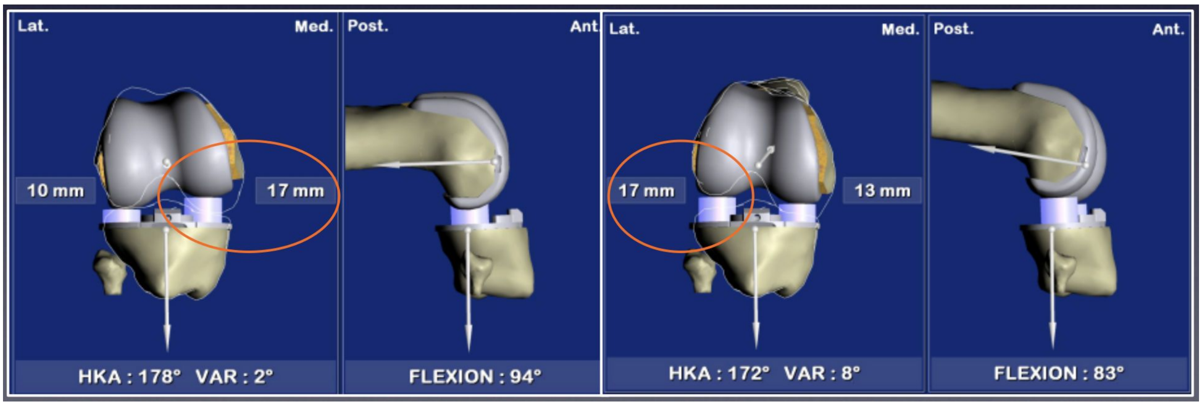

Figure 8: Measurement of the tibiofemoral space in forced varus and valgus, using the Amplivision navigation system

DISCUSSION

Patellofemoral complications are frequent causes of revision surgery in total knee replacements (12-15). Rotational alignment of the femoral component directly influences the patellofemoral joint as well as flexion gap balancing (3, 14-17) and therefore clinical outcomes. It is essential to adjust the femoral component in rotation (16, 18-19), applying the same precision as for alignment in the frontal and sagittal planes.

Paradoxically, if we pay particular attention to ligament balance in extension and flexion by adjusting the rotation of the femoral component, we have no idea of the consequences of these choices for patellofemoral kinematics. The technique presented here provides an alternative to address this issue. Making it a central tenet to place the femur component parallel to the natural trochlea will dictate the rotation alignment of the femoral component. One crucial point in this study consists in ensuring that rotational adjustment of the femoral component by trochlear navigation is not detrimental to achieve a balanced flexion space.

The outcomes of patellofemoral tracking assessed on Merchant's views at 30 and 60° appeared to be most satisfactory, compared with those usually published in the literature (12). If this study does not aim to prove that trochlear navigation improves the clinical outcome of a total knee arthroplasty, it does seem to demonstrate that the technique allows the percentage of patellofemoral complications (shifting, tilting or subluxation) to be decreased

The results presented in Table 1 enable us to confirm, like many other authors, the great individual variability of the posterior condylar angle ranging from 0 to 11° (8, 20-25). This variability dooms any method that establishes external rotation a priori at a fixed, predetermined value (often 3° for supporters of this technique). In this study, the average posterior condylar angle produced by the navigation system is very close to that found by the computed tomographic studies (5° versus 6.5°). For a given angle value, the measurements obtained by the two methods are correlated with one another and concordant (Figure 11). Furthermore, the two different centres using the same technique obtained similar results (Figure 12). These results as a whole demonstrate that trochlear navigation is a reliable and reproducible method for adjusting the femoral casing in rotation.

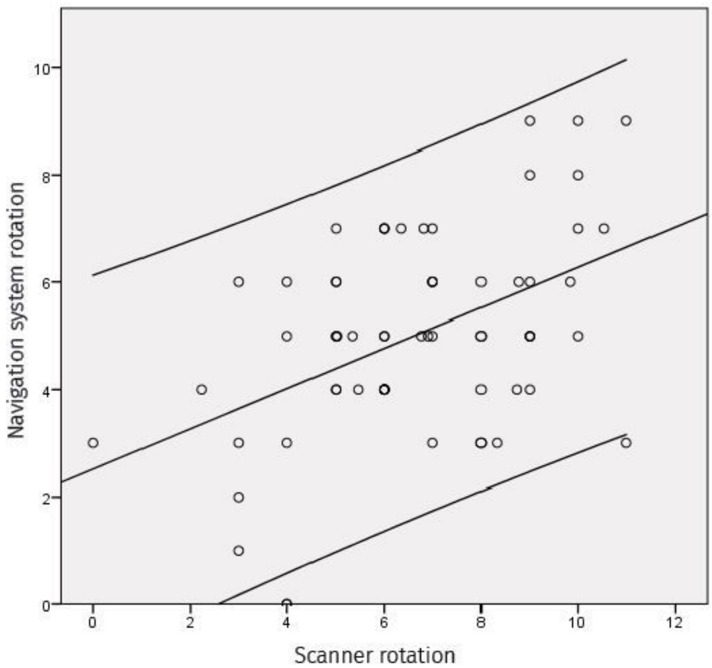

Figure 11: Diagram showing the correlation between the values for angular divergence between the posterior condylar plane and the condylar axis, produced by the navigation system and by computed tomographic analysis.

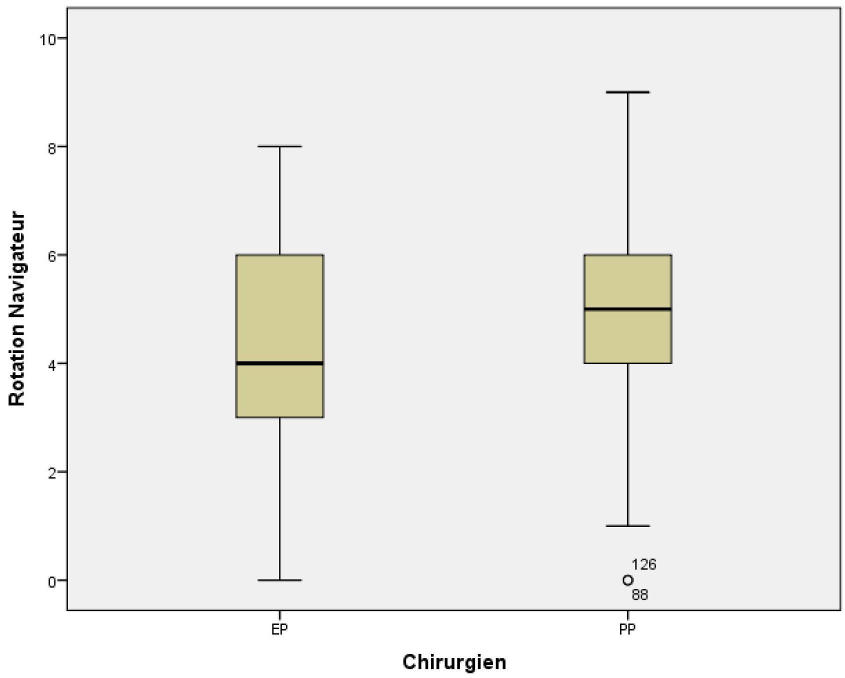

Figure 12: Comparison of the distributions of the values for angular divergence between the posterior condylar plane and the condylar axis for each of the operators, in centres A and B respectively.

The literature has well described the difficulty in identifying the transepicondylar axis visually or by navigation (4, 6, 26). None of the published methods currently allows precise and reproducible adjustment of the rotation of the femoral component (3). The technique presented here, which is totally original, therefore appears to contribute a superior precision and reproducibility in the pursuit of this goal. Some might criticize the technique by arguing that aligning the prosthetic trochlea below the extensor mechanism could cause difficulties to balance the flexion gap. Our results rebut this criticism with the data presented in Figure 13. Rotational adjustment using trochlear navigation allows a rectangular flexion.

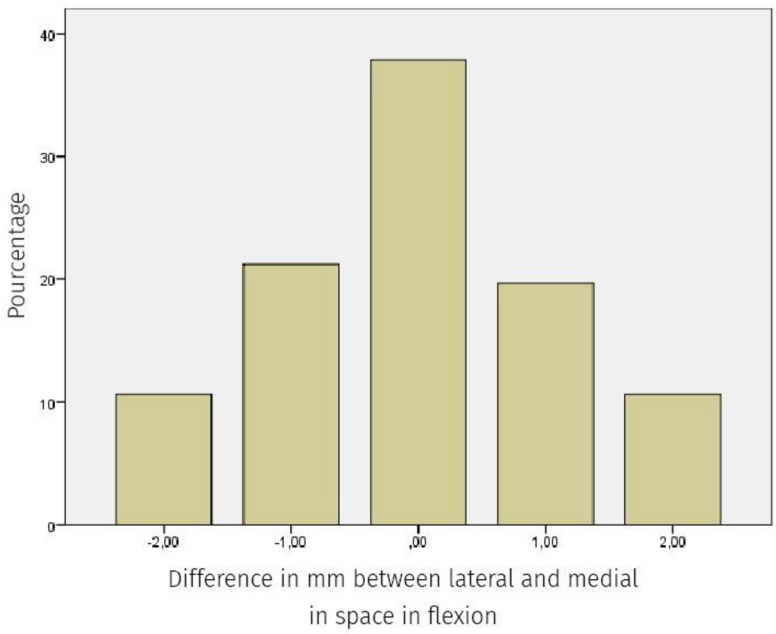

Figure 13: Difference in measurements between lateral and medial sides in flexion expressed in mm, measured by the navigation system with the knee flexed to 90°.

This method even works when the initial angular deformity is large. In actual fact, extensive ligament release in extension sometimes modifies the space in flexion quite ‘anarchically’. In these cases, use of a tensioning device may be the cause of ‘aberrant’ rotation of the femoral component.

The technique presented here does not have this problem. Indeed, trochlear navigation enables any major rotational malalignment of the femoral component to be eliminated. In this study it could be proven that no femoral component was positioned in internal rotation, as verified by postoperative computed tomography.

Trochlear navigation thus provides an additional tool to assist the surgeon in determining femoral component alignment. It enables perfect superimposition of the prosthetic trochlea on the native trochlea in order to facilitate patellofemoral kinematics. Concomitantly it allows ligament balance for the flexion gap. Two intraoperative strategies are possible with trochlea navigation:

- either rotation of the femoral component is initially determined by balancing the flexion gap (tensioning device; navigated measurement of the flexion gap). The surgeon will then be able to use trochlear navigation to assess the consequences of this choice for patellofemoral kinematics.

- or rotation of the femoral component is initially determined by trochlear navigation and, as a secondary factor, the surgeon will be able to assess the consequences of this choice for the flexion gap.

Trochlear navigation is currently the only method that enables mediolateral alignment of the femoral component to be accurately determined. In this study, use of a total knee replacement in which the trochlea is centred forced us to lateralize the femoral component by an average of 2.4 mm [0; 5 mm] in relation to the distal femoral cut. This almost systematic lateralization seems problematic to us, as it increases the risk of lateral overhang of the femoral component. During a morphometric study of the distal femur done on 376 femurs (27), carried out during the development of the Anatomique prosthesis (Amplitude), we were able to confirm these results (average lateralization of the trochlea by 2.3 mm). The outcome led us to design a femoral component with a lateralized trochlea position to allow a self-centring of the patella and to limit the risk of lateral overhang.

CONCLUSION

This study demonstrated that trochlear navigation, quite apart from its originality, is a reliable and reproducible method for adjusting rotational alignment and mediolateral positioning of the femoral component during knee arthroplasty. The precision achieved with trochlear navigation appears to be superior to that of other methods published in the literature. It means that with trochlear navigation rotational malpositioning along with its anatomical and clinical consequences might be avoided. Furthermore, trochlear navigation provides a useful tool for the intraoperative assessment of the impact of femoral component alignment on patellofemoral kinematics.

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