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ORIGINAL ARTICLE

Rotational positioning of the tibial tray in total knee arthroplasty: A CT evaluation

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KEYWORDS
Knee;
Total knee arthroplasty;
Tibial rotation;
Computed tomography scanning (CT scanning);
Tibial component positioning

Summary
Introduction: Various surgical techniques have been described to set the rotational alignment of the tibial baseplate during total knee arthroplasty. The self-positioning method (''self-adjustment'') aligns the tibial implant according to the rotational alignment of the femoral component which is used as a reference after performing repeated knee flexion/extension cycles. Postoperative computed tomography scanning produces accurate measurements of the tibial baseplate rotational alignment with respect to the femoral component.
Hypothesis: The rotational positioning of the tibial baseplate matches the rotation of the femoral component with parallel alignment to the prosthetic posterior bicondylar axis.
Patients and methods: A 3-month follow-up CT scan was carried out after primary total knee arthroplasty implanted in osteoarthritic patients with a mean 7.8° varus deformity of the knee in 50 cases and a mean 8.7° valgus deformity of the knee in 44 cases. The NexGen LPS Flex (Zimmer) fixed-bearing knee prosthesis was used in all cases. An independant examiner (not part of the operating team) measured different variables: the angle between the anatomic transepicondylar axis and the posterior bicondylar axis of the femoral prosthesis (prosthetic posterior condylar angle), the angle between the posterior bicondylar axis and the posterior marginal axis of the tibial prosthesis, the angle between the posterior marginal axis of the tibial prosthesis and the posterior marginal axis of the tibial bone and finally the angle between the anatomic transepicondylar axis and the posterior marginal axis of the tibial prosthesis.
Results: For the genu varum and genu valgum subgroups, the mean posterior condylar axis of the femoral prosthesis was 3.1° (SD: 1.91; extremes 0° to 17.5°) and 4.7° (SD: 2.7; extremes 0° to 11°) respectively. The tibial baseplate was placed in external rotation with respect to the femoral component: 0.7° (SD : 4.45; extremes −9.5° to 9.8°) and 0.9° (SD: 4.53; extremes

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−10.8° to 9.5°), but also to the native tibia: 6.1° (SD: 5.85; extremes −4.6° to 22.5°) and 12.5° (SD: 8.6; extremes −10° to 28.9°). The tibial component was placed in internal rotation relative to the anatomic transepicondylar axis: 1.9° (SD : 4.93; extremes −13.6° to 7°) and 3° (SD : 4.38; extremes −16.2° to 4.8°).

Discussion: The tibial component is aligned parallel to the femoral component whatever the initial frontal deformity ($P \cong 0.7$). However, a difference was observed between the rotational alignment of the tibial baseplate and the native tibia depending on the initial deformity and could be attributed to the morphological variations of the bony tibial plateau in case of genu valgum.

Conclusion: The self-positioning method is a reproducible option when using this type of implant since it allows the tibial component to be positioned parallel to the posterior border of the femur.

Level of evidence: Level III. Observational prospective study.

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Introduction

Accurate rotational alignment of the tibial and femoral components is the third requirement for successful 3D positioning of a total knee prosthesis. This rotational alignment has a major influence on tibiofemoral [1—4] and patellofemoral kinematics [5—8]. Rotational alignment of the femoral component has been the subject of various anatomical [1,9—11] and surgical studies first to evaluate the distal femoral torsion and the degree of implant rotation [12,13], but also to assess the intraoperative [14,15] and above all preoperative landmarks based on CT data [12—16] in order to adapt implant rotation to the patient's specific anatomy.

Proper evaluation of tibial positioning in the transverse plane is made difficult by the anatomical variability [17], but also the difficulty to identify reliable landmarks to provide precise rotational alignment of the tibial component, even when based on preoperative CT scans [18].

Various surgical techniques have been described for accurate positioning of the tibial baseplate in the transverse plane during total knee arthroplasty: the anterior border of the tibia [19], the anterior tibial tubercle [20], the transverse axis of the tibia [17], the transepicondylar axis [21], the bi-malleolar axis [22]. Each of these options reports a great variability in references which leads to a highly variable tibial component positioning. The self-positioning (''self-adjustment'') method aligns the tibial implant with respect to the rotational alignment of the femoral component which is used as a reference after knee flexion/extension cycles.

This method is ''dependent'' on femoral positioning and appears relevant under two conditions:

- alignment of the tibial component under the femur is real and reproducible;
- the rotational positioning of the femoral component is reliable. This is why we use an individual rotational alignment adapted to each specific knee based on a systematic preoperative CT scan measurement of the posterior condylar angle thus allowing to intraoperatively adapt the femoral rotational alignment through computer assisted navigation, the posterior border of the femoral implant being therefore parallel to the surgical transepicondylar axis.

Our objective was to measure the tibial baseplate positioning in the transverse plane with respect to the femoral component by means of a postoperative CT study after total knee prosthesis implantation through the medial or lateral approach in patients with varus or valgus deformity of the knee. According to our hypothesis, the tibial component positioning would match the rotation of the femoral component, the tibial component being parallel to the posterior bicondylar axis of the femoral prosthesis.

Patients and methods

Patients

This prospective non-randomized study was conducted between March 2008 and December 2009. A CT scan of 95 knees was performed in 87 patients 3 months after primary implantation of a total knee prosthesis in the management of osteoarthritis of the knee. Ninety-four knees were included in this study. Two subgroups were made: a genu varum subgroup operated on through the medial parapatellar approach and a genu valgum subgroup operated on through the lateral parapatellar approach:

- 50 knees with a mean 7.8° frontal deviation (extremes 1° to 17.5°) and distal epiphyseal femoral torsion of 4.9° (extremes 2° to 7°) were operated on through the medial parapatellar approach. The mean body mass index (BMI) in this subgroup was 28.1 kg/m^2;
- 45 knees with a mean 8.7° valgus deviation (extremes 1° to 18°) and a distal epiphyseal femoral torsion of 6.1° (extremes 2° to 10°) were operated on through the lateral parapatellar approach. The mean BMI in this subgroup was 26.8 kg/m^2.

Knowing the influence of the sugical approach on rotational alignment of the tibial implant [23], and in order to simplify the study groups, all cases of genu varum operated on through the lateral approach (patellar subluxation or hardware removal for example) and all cases of genu valgum operated on through the medial approach were excluded from this study. Were also excluded all cases of revision surgery of uni- or tricompartmental arthroplasties.

The NexGen LPS Flex (Zimmer) fixed-bearing and symmetrical knee prosthesis was implanted. This is a semi-constrained prosthesis with 12° of rotational freedom in extension (data from the manufacturer). Two options of implant keel were used at random according to the operator's preferences: a 45 mm standard keel featuring an angular section or a ''mini-keel'' featuring a pyramid-shape section. The metallic trial tibial plateau was identical in both cases and the keel shape could not influence rotation. The femoral and tibial bone cuts were performed independently starting with the distal femoral cut. Rotation of the femoral component was adjusted using computer assisted navigation (3.6° [extreme values 2° to 5°] for the genu varum subgroup and 4.2° [extreme values 1° to 7°] for the genu valgum subgroup). The objective was to achieve a prosthetic posterior condylar angle of 3° ± 2° relative to the anatomic transepicondylar axis of Yoshioka et al. [24], in order to place the implant parallel to the surgical transepicondylar axis which is similar to the knee flexion axis [16]. Computer assisted navigation was not used for rotational alignment of the tibial component, the objective being to place the trial tibial component parallel to the femoral component in full extention, according to the ''self-adjustment'' method. The operator was placed lateraly relative to the patient while performing flexion-extension movements of the knee. The patella was maintained in the reduced position to prevent any tibial rotation [25]. Rotational orientation of the trial tibial component was evaluated with the knee placed in extension. The tibial slope provided by the sagittal CT view was 6° according to the manufacturer requirements.

Methods

The CT scan protocol was that proposed by the ''Société française de la hanche et du genou'' (SFHG) during the symposium of the 2007 SOFCOT congress [26]. Measurements were performed twice at one month interval by the same non-operator examiner (JB), using the Dicom Toolbox vl.2 software on Dicom images. Were measured:

- the prosthetic posterior condylar angle (PCA TKA), that is, the angle between the anatomic transepicondylar axis (TEA) and the posterior bicondylar axis of the femoral component (PBCf TKA) (Fig. 1);
- the angle between the TEA and the posterior marginal axis of the tibial prosthesis (PMAt TKA). It corresponded to the rotation given to the tibial component with respect to the native femur. The aim was the same as the 3° ± 2° prosthetic posterior condylar angle (Fig. 1);
- the angle between the posterior marginal axis of the tibial prosthesis (PMAt TKA) and the posterior marginal axis of the tibial bone (native PMAt), obtained by superimposing the CT view passing through the tibial baseplate and the tibial CT view passing just below the metallic tibial baseplate. The objective was to evaluate the tibial component positioning in the transverse plane with respect to the native tibia (Fig. 2);
- the angle between the posterior bicondylar axis of the femoral prosthesis (PBCf TKA) and the posterior marginal axis of the tibial prosthesis (PMAt TKA). This angle was obtained by superimposing the two views passing through the posterior bicondylar axis on one hand and through the tibial baseplate on the other hand. It represented the rotational alignment of the tibial baseplate relative to the femoral component. The objective was 0° ± 2° (Fig. 1).

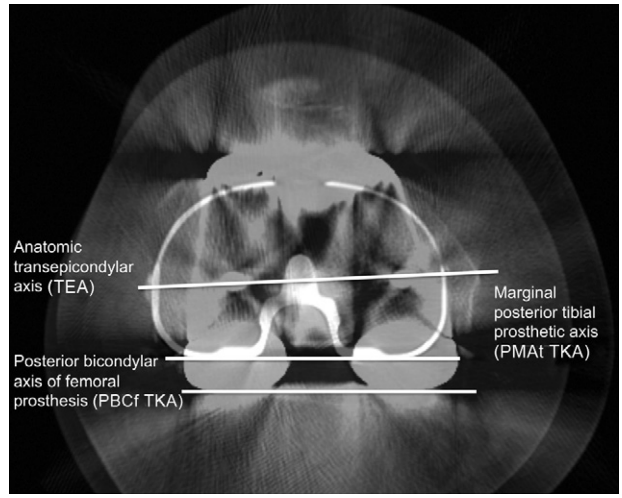

Figure 1 Right knee: method of measurement of the prosthetic posterior condylar angle (PCA TKA) between the anatomic transepicondylar axis (TEA) and the posterior bicondylar axis of the femoral prosthesis (PBCf TKA), the angle between the anatomic transepicondylar axis (TEA) and the posterior marginal axis of the tibial prosthesis (PMAt TKA), the angle between the posterior bicondylar axis of the femoral prosthesis (PBCf TKA) and the posterior marginal axis of the tibial prosthesis (PMAt TKA).

Measurements were given the + sign when the tibial component was lateraly rotated relative to the femoral component and the − sign otherwise.

Statistical methods

For descriptive analysis, data were presented by median and interquartile range (25th; 75th percentiles). Non-paired

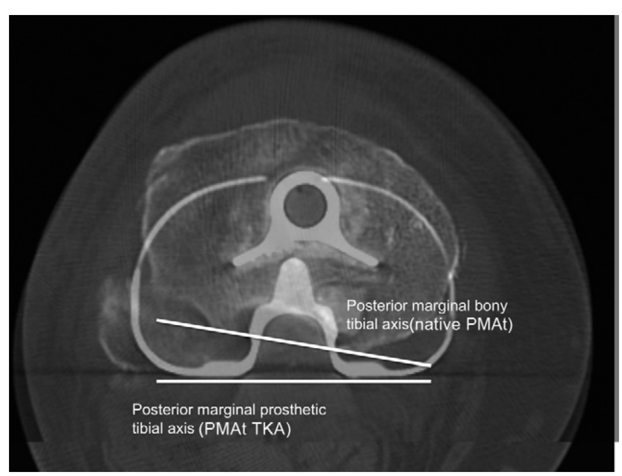

Figure 2 Right knee: method of measurement of the angle between the posterior marginal axis of the tibial prosthesis (PMAt TKA) and the posterior marginal axis of the native tibia (native PMAt).

Table 1 Angular measurements expressed in degrees for the genu varum — medial parapatellar approach subgroup: Posterior condylar angle (PCA), rotational alignment of the tibial base plate relative to the native femur (TEA angle / PMAt TKA), relative to the native tibia (PMAt TKA / native PMAt) and relative to the femoral component (PBC angle f TKA / PMAt TKA).

	PCA TKA	TEA angle / PMAt TKA	PMA angle t TKA / native PMAt	PBC angle f TKA / PMAt TKA
Mean	3.14	−1.89	6.11	0.75
Standard deviation	1.91	4.93	5.85	4.45
Minimum	0.0	−13.60	−4.60	−9.50
25th percentile	1.95	−5.03	1.175	−1.950
Median	3.00	−1.85	4.90	0.70
75th percentile	4.00	1.6	10.43	3.83
Maximum	7.00	7	22.50	9.2

quantitative data were compared using the Mann Whitney non-parametric test for comparisons between two groups of variables and using the non-parametric variance analysis to evaluate the intra-observer variability. *P* values inferior to 0.05 were considered statistically significant. The statistical analysis was performed using the R 2.12.0 software.

Results

For both series of measurements, the intra-observer variability was not statistically significant (variation coefficient between the two series less than 6%). Ninety-four postoperative CT scans were analyzed. One CT scan examination performed in another center could not be analyzed.

In the genu varum — medial parapatellar approach subgroup, the prosthetic posterior condylar angle was 3.14° (SD: 1.91; extremes 0° to 17.5°) for an objective of 3° ± 2°. The tibial baseplate was placed in 1.9° of internal rotation (SD: 4.93; extremes −13.6° to 7°) relative to the anatomic transepicondylar axis for an objective of 3° ± 2°. The tibial component was placed in 6.1° of external rotation (SD: 5.85; extremes −4.6° to 22.5°) relative to the native tibia. The tibial baseplate was placed in 0.7° of external rotation (SD: 4.45 ; extremes −9.5 to 9.2) relative to the femoral component (Table 1).

In the genu valgum — lateral parapatellar approach subgroup, the prosthetic posterior condylar angle was 4.72° (SD: 2.7 ; extremes 0° to 11°) for an objective of 3° ± 2°. The tibial baseplate was placed in 3° of internal rotation (SD: 4.38; extremes −16.2° to 4.8°) relative to the anatomic transepicondylar axis for an objective of 3° ± 2°. The tibial component was placed in 12.52° of external rotation (SD: 8.6; extremes −10° to 28.9°) relative to the native tibia. The tibial baseplate was placed in 0.9° of external rotation (SD: 4.53; extremes −10.8° to 9.5°) relative to the femoral component (Table 2).

In both groups, the self-adjustment method was used to achieve a parallel alignment of the two prosthetic components with no difference being established between the genu varum - medial approach and genu valgum — lateral approach subgroups ($P \cong 0.72$). The relative femoral hyporotation in the genu valgum subgroup (4.7° versus 3.2°; $P \cong 0.005$) was associated with a higher internal rotation of the tibial component (3° versus 1.9°) relative to the anatomic transepicondylar axis ($P \cong 0.25$). The external rotation of the tibial component relative to the native tibia was significantly lower in the genu varum — medial approach subgroup than in the genu valgum — lateral approach subgroup ($P < 0.0001$).

Discussion

There is no consensus regarding the standard reference used for tibial baseplate positioning during total knee arthroplasty. However, this point is essential as tibial component malrotation may induce a risk of early loosening due to the lack of homogeneous stress distribution, but also an unbalanced patellofemoral joint kinematics associated with a higher risk of instability particularly in case of internal rotation of the tibial component [6,27].

Table 2 Angular measurements expressed in degrees for the genu valgum — lateral parapatellar approach subgroup: posterior condylar angle (PCA), tibial base plate rotation relative to the native femur (TEA angle / PMAt TKA), relative to the native tibia (PMA angle TKA) and relative to the femoral component (PBC angle f TKA / PMAt TKA).

	PCA TKA	TEA angle / PMAt TKA	PMA t TKA / native PMAt	PBC angle f TKA / PMAt TKA
Mean	4.72	−3.0	12.52	0.96
Standard deviation	2.7	4.38	8.60	4.53
Minimum	0.0	−16.20	−10.0	−10.80
25th percentile	3	−5.78	5.2	−1.23
Median	4.3	−2.3	14.80	0.95
75th percentile	6.0	−0.7	18.78	2.98
Maximum	11.0	4.80	28.90	9.50

Numerous methods or landmarks have been proposed to achieve accurate rotational alignment of the tibial baseplate. Referencing the tibial rotation between the medial third and the two lateral thirds of the anterior tibial tubercle (ATT) or using the medial border of the patellar tendon as a landmark for tibial rotational alignment could be a satisfying method with limited postoperative patellofemoral pain. However, these landmarks vary greatly between patients particularly in case of patellofemoral dysplasia; therefore, this landmark cannot be considered as reliable [28].

According to Akagi et al. [19], positioning of the tibial implant at right angle to the anteroposterior axis drawn between the posterior cruciate ligament (PCL) insertion and the medial border of the patellar tendon, passing through the geometrical center of the knee, could ensure a precise rotational alignment relative to the femoral component. Measurement of the tibial rotation according to the angle between the anteroposterior axis described by Akagi et al. [19] and an anteroposterior axis orthogonal to the femoral transepicondylar axis and passing through the PCL insertion, would also be the most reproducible. According to Page [29], positioning of the tibial baseplate relative to the anterior tibial marginal line appears to be the method which reports the lowest variability.

In the absence of precise and easily identifiable tibial anatomical landmark, the self-adjustment method uses the posterior border of the femoral condyles on which is aligned the tibial baseplate after flexion/extension cycling movements of the knee. Such method, which has been criticized by Nagamine et al. [30] and Ikeuchi et al. [31] is relevant only in case of reliable rotational alignment of the femoral component since it is a ''dependent'' method similarly to the dependent femoral and tibial bone cuts performed in the frontal plane. When admitting that the rotational axis of the knee is the surgical transepicondylar axis of Berger et al. [9] and that femoral implant rotation is calculated to be parallel to this surgical axis (that is 3° relative to the anatomical axis of Yoshioka et al. [24]), therefore this axis may be considered as a reliable reference for rotational alignment of the tibial component. Preoperative measurement of the posterior condylar angle should therefore be systematically carried out using CT scanning.

Whatever the initial frontal deformity and the chosen surgical approach in our study, the tibial component is positioned parallel to the femoral component (less than approximately 1°), whereas the theoretical intraprosthetic rotation is 12°. The self-adjustment method is thus reliable and reproducible since it provides an accurate femur-tibia parallelism with the posterior bicondylar axis of the femoral prosthesis placed parallel to the posterior marginal axis of the tibial component.

When rotational positioning of the femoral implant is adapted (3.2° in the genu varum subgroup, 4.7° in the genu valgum subgroup for an objective of 3°), therefore the rotational alignment of the tibial implant with respect to the anatomic transepicondylar axis (1.9° in the genu varum subgroup and 3° in the genu valgum subgroup) is also adapted as both components are parallel to one another which confirms our initial hypothesis.

No significant differences could be observed between the two groups regarding these three angles (prosthetic posterior condylar angle, the angle between the posterior bicondylar axis and the tibial base plate, the angle between the transepicondylar axis and the tibial base plate). However, in the genu valgum subgroup, the rotational alignment of the tibial base plate with respect to native tibia, taking the posterior marginal line as a reference, is twice higher than in the genu varum subgroup, which confirms the results of a previous study [23]. Methodologically, the native posterior tibial marginal line may be difficult to identify on postoperative CT scans due to the presence of osteophyte remnants but also due to the cutting level which must be taken into account just below the prosthetic plateau with a variable thickness of the polyethylene insert. However, this measurement is reproducible and demonstrates a low intra-observer variability (< 6%). Such difference in the rotational alignment of the tibial component with respect to the bony tibial plateau — whereas positioning relative to the femur is identical in both groups — can only be induced by morphological variations in tibial plateau between the genu varum and genu valgum subgroups. The anatomy of the lateral femoral condyle in patients with genu valgum has been widely described [32], whereas no studies have been conducted on the tibia anatomical features to date. According to recently published works, there is a close relationship between the tibial rotation and the tibial surface morphology.

Conclusion

The self-adjustment technique is a reliable method for proper positioning of the tibial baseplate in the axial plane since it is placed parallel to the femoral component. This dependent technique is relevant only when rotational alignment of the femoral component is adapted to the patient's specific anatomy (by means of preoperative CT scanning) to achieve a precise alignment of the femoral and tibial components relative to the surgical transepicondylar axis. The difference in rotation between the tibial implant and the native tibia, which depends on the initial frontal deformity, underlines the specific tibial plateau morphology in patients with genu valgum.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

[1] Miller MC, Berger RA, Petrella AJ, Karmas A, Rubash HE. Optimizing femoral component rotation in total knee arthroplasty. Clin Orthop Rel Res 2001;392:38—45.

[2] Moreland JR. Mechanisms of failure in total knee arthroplasty. Clin Orthop Rel Res 1988;226:49—64.

[3] Bargren JH, Blaha JD, Freeman MA. Alignment in total knee arthroplasty. Correlated biomechanical and clinical observations. Clin Orthop Rel Res 1983;173:178—83.

[4] Akagi M, Matsusue Y, Mata T, Asada Y, Horiguchi M, Iida H, Nakamura T. Effect of rotational alignment on patellar tracking in total knee arthroplasty. Clin Orthop Rel Res 1999;366:155—63.

[5] Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop Rel Res 1998;356:144—53.

[6] Matsuda S, Miura H, Nagamine R, Urabe K, Hirata G, Iwamoto Y. Effect of femoral and tibial component position on patellar tracking following total knee arthroplasty: 10-year follow-up of Miller-Galante I knees. Am J Knee Surg 2001;14:152—6.

[7] Asano T, Akagi M, Koike K, Nakamura T. In vivo three-dimensional patellar tracking on the femur. Clin Orthop Rel Res 2003;413:222—32.

[8] Rhoads DD, Noble PC, Reuben JD, Mahoney OM, Tullos HS. The effect of femoral component position on patellar tracking after total knee arthroplasty. Clin Orthop Rel Res 1990;260:43—51.

[9] Berger RA, Rubash HE, Seel MJ, Thompson WH, Crossett LS. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Rel Res 1993;286:40—7.

[10] Victor J, Van Doninck D, Labey L, Van Glabbeek F, Parizel P, Bellemans J. A common reference frame for describing rotation of the distal femur: a CT based kinematic study using cadavers. J Bone Joint Surg (Br) 2009;91:683—90.

[11] Victor J. Rotational alignment of the distal femur: a literature review. Orthop Traumatol Surg Res 2009;95:365—72.

[12] Galaud B, Beaufils P, Michaut M, Abadie P, Fallet L, Boisrenoult P. Distal femoral torsion: comparison of CT scan and intraoperative navigation measurements during total knee arthroplasty. A report of 70 cases. Rev Chir Orthop 2008;94:573—9.

[13] Fehring TK. Rotational malalignment of the femoral component in total knee arthroplasty. Clin Orthop Rel Res 2000;380: 72—9.

[14] Jenny JY, Boeri C. Low reproducibility of the intraoperative measurement of the transepicondylar axis during total knee replacement. Acta Orthop Scand 2004;75:74—7.

[15] Poilvache PL, Insall JN, Scuderi GR, Font-Rodriguez DE. Rotational landmarks and sizing of the distal femur in total knee arthroplasty. Clin Orthop Rel Res 1996;331:35—46.

[16] Michaut M, Beaufils P, Galaud B, et al. Rotational alignment of femoral component with computed-assisted surgery (CAS) during total knee. Rev Chir Orthop 2008;94:580.

[17] Victor J, Van Doninck D, Labey L, Innocenti B, Parizel PM, Bellemans J. How precise can bony landmarks be determined on a CT scan of the knee? Knee 2009;16:358—65.

[18] Akagi M, Oh M, Nonaka T, Tsujimoto H, Asano T, Hamanishi C. An anteroposterior axis of the tibia for total knee arthroplasty. Clin Orthop Rel Res 2004;420:213—9.

[19] Akagi M, Mori S, Nishimura S, Nishimura A, Asano T, Hamanishi C. Variability of extraarticular tibial rotation references for total knee arthroplasty. Clin Orthop Rel Res 2005;436:172—6.

[20] Huddleston JI, Scott RD, Wimberley DW. Determination of neutral tibial rotational alignment in rotating platform TKA. Clin Orthop Rel Res 2005;440:101.

[21] Aglietti P, Sensi L, Cuomo P, et al. Rotational position of femoral and tibial components in TKA using the femoral transepicondylar axis. Clin Orthop Rel Res 2008:466.

[22] Lemaire P, Pioletti DP, Meyer FM, et al. Tibial component positioning in total knee arthroplasty: bone coverage and extensor apparatus alignment. Knee Surg Sports Traumatol Arthrosc 1997;5:251.

[23] Passeron D, Gaudot F, Boisrenoult P, Fallet L, Beaufils P. Does lateral versus medial exposure influence total knee tibial component final external rotation? A CT based study. Orthop Traumatol Surg Res 2009;95:420—4.

[24] Yoshioka Y, Siu D, Cooke DV. The anatomical and functional axis of the femur. J Bone Joint Surg (Am) 1987;69:873—80.

[25] Gejo R, McGarry M, Jun B, Hofer JK, Kimura T, Lee TQ. Biomechanical effects of patellar positioning on intraoperative knee joint gap measurement in total knee arthroplasty. Clin Biomech 2010;25:352—8.

[26] Bonnin M, Beaufils P. Complications fémoro-patellaires des prothèses totales de genou. Alignement des pièces fémorale et tibiale. Réunion ouverte SFHG 2007. http://www.sfhg.fr/200720SOFCOT/compli20fp20ptg/bonnin.html.

[27] Barrack RL, Schrader T, Bertot AJ, Wolfe MW, Myers L. Component rotation and anterior knee pain after total knee arthroplasty. Clin Orthop Rel Res 2001;392:46—55.

[28] Bonnin MP, Saffarini M, Mercier PE, Laurent JR, Carrillon Y. Is the anterior tibial tuberosity a reliable rotational landmark for the tibial component in total knee arthroplasty? J Arthroplasty 2011;26:260—7.

[29] Page SR, Deakin AH, Payne AP, Picard F. Reliability of frames of reference used for tibial component rotation in total knee arthroplasty. Comput Aided Surg 2011;16:86—92.

[30] Nagamine R, Whiteside LA, Otani T, White SE, McCarthy DS. Effect of medial displacement of the tibial tubercle on patellar position after rotational malposition of the femoral component in total knee arthroplasty. J Arthroplasty 1996;11:104—10.

[31] Ikeuchi M, Yamanaka N, Okanoue Y, et al. Determining the rotational alignment of the tibial component at total knee replacement. A comparison of two techniques. J Bone Joint Surg (Br) 2007;89:45—50.

[32] Brilhault J, Preyssas P, Favard L, Burdin P. Dimensions of the lateral condyle in non-arthritic valgus knees. A cadaver study. Rev Chir Orthop 2002;88:686—90.