Hamelynck, Karel J., Amsterdam, NL and Stiehl, James, B., Milwaukee, USA (Eds.)

with a Foreword by Frederick .F Buechel and Michael J. Pappas:

LCS Mobile Bearing Knee Arthroplasty

- 25 Years of Worldwide Experience -

Femoral Rotation Based on Tibial Axis: The LCS Method

J.G. BOLDT, P. KEBLISH AND J.B. STIEHL

Jens G. Boldt,

Schulthess Klinik, Lengghalde 2CH-8008 Zurich, Switzerland

Telephone: +41 1385 7585

E-mail: jgboldt@hotmail.com

Femoral rotation positioning is critical for successful TKA. Three different methods of referencing are generally accepted. These include the transepicondylar axis (TEA), as advocated by Insall, arbitrary external rotation from the posterior condyles, and the so-called Whiteside line. Another less well recognized method, which has been used for over 20 years is referencing femoral component rotation perpendicular to the tibial shaft axis via a balanced flexion tension gap. Placing the femoral component parallel to the TEA leads to a biomechanically sound knee motion in full flexion and extension. However, this method has potential errors that include any anatomical deviations of the distal femur, which may occur in cases with severe varus or valgus angle deformity, condylar dysplasia, or other rotational pathology of the lower extremity.

Clinical outcomes after TKA are dependent upon multifactorial issues; one of which is femoral component rotational alignment. Prosthetic design and implantation of femoro-tibial components vary with different total knee systems. The surgeon must evaluate and address variables that include varus-valgus alignment, extra-articular deformities, soft tissue contractions, exaggerated Q angle, patella position, size, and shape as well as femoro-tibial rotation. Intraoperative variables include surgical approach, femoro-tibial stability, soft tissue management, extensor mechanism and patella treatment, prosthetic selection and positioning. Femoral component rotational alignment has gained more attention in the recent literature, since component mal-positioning “negatively” influences knee kinematics, including patello-femoral tracking and range of motion.

The TEA is the most commonly referenced anatomic landmark for rotational positioning of the femoral component in TKA. It is reported as being more predictable than Whiteside’s line or the posterior condyle. However, the TEA depends on estimated landmarks and may be altered in both varus and valgus knees and/or other pathological variations that may change lower limb rotational axes. Tibial rotation position, an important consideration in fixed bearing designs, is also a factor that affects gap balance and the patello-femoral joint. Tibial rotational positioning is of lesser concern in mobile-bearing TKA because of the ability (of the bearing) to adapt to tibio-femoral rotation in flexion and extension.

Rotational mal-positioning creates a trapezoidal rather than rectangular flexion gap with an altered patello-femoral articulation and unbalanced femoro-tibial kinematics. Instability in flexion with a tighter medial and more lax lateral compartment occurs when the femoral component is internally mal-rotated. This is frequently combined with lateral patello-femoral subluxation and instability (lift-off) of the lateral compartment in flexion. In most TKA systems, for a given amount of tibial resection, there is an appropriate amount of posterior condylar resection required to create a symmetric flexion gap. Different opinions of surgical approach exist regarding soft tissue releases, tibia first or femoral first bone cuts, as well as the femoral rotation resection. The most common method of tibial resection is perpendicular to the mechanical axis with some posterior inclination.

Figure 1 and 2

The three established methods of determining femoral rotational positioning in TKA consist of: the transepicondylar axis as advocated by Insall (Fig. 1), Whiteside's line, or a line perpendicular to the antero-posterior femoral axis (Fig. 2), referencing 3 to 4° external rotation from the posterior condyles (Fig. 3). The posterior condylar reference as described by Hungerford (Fig. 4) is seldom utilized since it results in consistent femoral internal rotational positioning, often excessive. The LCS method is based on the tibial shaft axis and balanced flexion gap and has been utilized since 1977 with mobile bearing TKA (Fig. 5). Potential advantages and errors of each method will be discussed.

Figure 3 and 4

Figure 5

Olcott and Scott have recently reported that these three widely accepted methods were consistent in yielding a symmetric, balanced flexion gap within 3°. However, significant variable and inconsistencies were noted. The transepicondylar axis failed to yield flexion gap symmetry in 10% of neutral varus TKA and 14% valgus TKA, with discrepancies varying from 9° too little to 6° too much external rotation, which is less than desirable. The authors recommended using a combination of these methods to avoid potential mal-resections.

Clinical studies by Stiehl and Cherveny compared the tibial shaft axis method to other methods for determining femoral rotation in four different fixed bearing knee systems utilizing a femoral first approach. With the post condylar method, 72% required lateral release with 7% patella fractures reported. When 4 to 5° of external rotation method was used, 28% lateral release were reported. When the tibial shaft axis method was utilized, femoral component placement was reported within 1º of external rotation compared to the TEA. There were decreased number of lateral releases required and no patella complications. Katz et al. showed in a cadaver study of eight knees (a three surgeon evaluation) that determination of femoral component rotational positioning was more reliable using a balanced flexion gap and the antero-posterior axis. A similar study performed by Jerosch et al. emphasized that the inaccuracy of anatomically identifying the TEA of the femur by eight surgeon in three knee cadavers was 23 degrees. Intraoperative evaluation of the femoral epicondyles and the TEA is less predictable and accurate than previously established methods. The method used to define femoral rotation with the LCS system is referenced on a tibial cut perpendicular to the tibial shaft axis and a symmetrical (rectangular) flexion gap. This method automatically defines the position of the free moveable femoral resection guide (Fig. 6),

Figure 6

avoiding the need of identifying anatomical landmarks. A rectangular spacer block is then applied to the rotationally unconstrained femoral component and sits flat on the tibial resection. The flexion tension is set and checked for proper balance (Fig. 7,8).

Figure 7 and 8

The extension gap is balanced to the flexion gap with a distal femoral resection, establishing the mechanical axis. (Fig. 9).

Figure 9

Comparison of this tibial axis method with the TEA methods adds to our understanding of this most important technique step in TKA. CT scan evaluation is the most accurate method to objectively assessing femoral component rotational placement compared to a known anatomic landmark post TKA. In order to clinically investigate the accuracy of the LCS method with regard to femoral component rotational positioning, we performed a study in which helical CT scan investigation was used referencing the femoral prosthetic placement to the transepicondylar axis. From a cohort of 3058 mobile bearing low contact stress (LCS, Depuy Int, Leeds, UK) TKA, 40 (1.3%) clinically well functioning knees were randomly selected for evaluation of femoral component rotational alignment. All patients with TKA in this center underwent routine clinical examination and follow-up radiographs at 1 week, 6 weeks, 1 year, 5 years, or when complications occurred. Mean age in this cohort was 67 years (range 54 to 77). Inclusion criteria for this subset was range of motion (ROM) over 100 degrees, lack of pre- or postoperative complications, and excellent or good clinical results according to a modified HSS 100-point clinical score with a mean of 91.2 points (81 to 100). One patient had to be excluded because of inability to identify appropriate anatomical landmarks on CT scans, and another patient refused CT investigation. Of the 38 cases available for this study, the patella was left unresurfaced in 36 (95%) cases, one was previously patellectomized, another patella was resurfaced using a metal-backed rotating patella component.

Follow-ups at regular intervals included a clinical evaluation and X-ray protocol. Radiographic analysis was focused on patella tracking, congruency, and patella tilt with comparable pre- and postoperative skyline radiographs. Patella tracking was based on alignment of the femoral trochlear sulcus and the crown of the patella and measured in millimeters of lateral deviation on comparable pre- and postoperative skyline views.

The ultimate 38 cases were randomly selected from patients who were scheduled by a computerized system for 1-, 5-, or 10-year routine follow-up. These patients were invited to participate in the study until the appropriate number was obtained. Of the two cases eliminated one patient refused to participate another was eliminated for technical reason as noted. Of this group all patients had excellent or good clinical results and no patient refused participation. The local university ethics committee approved the study.

All cases were investigated by one of two consultant musculoskeletal radiologists with CT experience of more than fifteen years. Before the start of the examination they examined a few patients not included into the investigation in order to use the same criteria, which were identical to those used for everyday examinations. The radiologists were not aware of the patients' knee status (single blinded). They were instructed not to talk with the patients about the status of their knees but about technical CT aspects only. All data for femoral component rotational positioning were analyzed using a helical CT scanner. Femoral component rotational alignment was calculated by referencing the two posterior condyles to the transepicondylar axis, which was a line drawn between the spike of the lateral epicondyle and the sulcus of the medial epicondyle as recently recommended by Yoshino et al. (Fig.10). One case was excluded because of inability to identify the medial sulcus despite 2mm cuts. Angles were calculated utilizing sophisticated helical CT-implemented software.

Figure 10

An independent statistician analyzed all data. The distribution of angles in each group were analyzed using the one-sample Kolmogorov-Smirnov test which indicates whether the number of cases is sufficient and a normal “bell-curve” distribution is demonstrated. A positive Kolmogorov-Smirnov test validates further parametric statistical analyses.

The subset of 38 cases (follow-up: 12 to 120 months) studied in this series had clinical results comparable to a larger cohort group of over 3000 TKA. All cases were well functioning knees with good or excellent clinical results. The mean ROM was 115° (range 100 to 135). Preoperatively, 3 of 38 cases had documented patella subluxation and tilt of more than 6°. Postoperatively all three achieved perfect patello-femoral tracking. Decreased height and sclerosis of the lateral patella facet was seen in two case without clinical symptoms. There were no fixation failures, no patella failures and no re-operations for any reason in this group.

Mean femoral alignment was near parallel (0.3° internal rotation) to the TEA with a range of 6° internal to 4° external rotation (Fig.11).

Figure 11

Standard deviation was 2.2 and standard error 0.4. All angles were normally distributed using one-sample Kolmogorov-Smirnov test, which validates a statistical mean value and outliers. Four cases fell outside of the predicted mean value (more than 3° internal or external rotation). Three had internal rotation and one case had external rotation. All four cases with maximum internal and external rotation showed perfect patello-femoral tracking on skyline views (Fig.12).

Figure 12

The data of our study emphasizes that correct femoral component rotational positioning, utilizing the tibial shaft axis method, results in a high level of consistency for accurate patello-femoral alignment and predictable clinical outcome (Fig.13).

Figure 13

In summary, femoral rotational alignment based on the tibial axis and balanced flexion tension is an instrumented technique that 1) avoids relationship to arbitrary landmarks; 2) establish a precise flexion gap which allows for a stable relationship to the corrected bio-mechanical axis; 3) is patient-specific regarding bone and soft tissue variations, 4) is reproducible (especially in severe deformities such as the valgus knee), and 5) results in predictable patella outcomes in reported series. Femoral component rotational alignment is technique- and instrument-dependent and influences patella tracking, gap balance, and soft tissue kinematics. Deviation into internal rotation results in less than ideal patello-femoral tracking and clinical outcomes. Potential complications, such as the painful and/or stiff TKA (arthrofibrosis) has been shown to correlate with significant internal rotation of the femoral component. The tibial shaft axis method as used with the LCS system provides perfect rotational alignment without anatomical landmark identification, and is, therefore, felt to be as or more predictable than all other currently practiced methods.

Acknowledgement:

C. Varma BS for illustrations (Allentown, PA, USA)

J. Hodler MD and M. Zanetti MD for helical CT data (Zurich, Switzerland)

T. Drobny MD for clinical support (Zurich, Switzerland)

P. Keblish MD for critical mansukript review

References:

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 1999 Sep;(366):155-63

Arima J, Whiteside LA, McCarthy DS, White SE. Femoral rotational alignment, based on the anteroposterior axis, in total knee arthroplasty in a valgus knee. A technical note. J Bone Joint Surg Am 1995;77(9):1331-4.

Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Rotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop 1998;(356):144-53

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 1993 Jan;(286):40-7

Buechel FF. A simplified evaluation system for the rating of the knee function. Orthop Rev 1982;11(9):97-101.

Churchill DL, Incavo SJ, Johnson CC, Beynnon BD. The transepicondylar axis approximates the optimal flexion axis of the knee. Clin Orthop 1998;(356):111-8.

Dennis DA, Komistek RD, Walker SA, Cheal EJ, Stiehl JB. Femoral condylar lift-off in vivo in total knee arthroplasty. J Bone Joint Surg Br 2001;83(1):33-9.

Eckhoff DG, Piatt BE, Gnadinger CA, Blaschke RC. Assessing rotational alignment in total knee arthroplasty. Clin Orthop 1995 Sep;(318):176-81

Engh GA. Orienting the femoral component at total knee arthroplasty. Am J Knee Surg 2000;13(3):162-5.

Fehring TK. Rotational malalignment of the femoral component in total knee arthroplasty. Clin Orthop 2000;380:72-9.

Fehring TK. Rotational malalignment of the femoral component in total knee arthroplasty. Clin Orthop 2000 Nov;(380):72-9

Griffin FM, Insall JN, Scuderi GR. Accuracy of soft tissue balancing in total knee arthroplasty. J Arthroplasty 2000 Dec;15(8):970-3

Griffin FM, Insall JN, Scuderi GR. The posterior condylar angle in osteoarthritic knees. J Arthroplasty 1998;13(7):812-5.

Hungerford DS. Alignment in total knee replacement.Instr Course Lect 1995;44:455-68

Katz MA, Beck TD, Silber JS, Seldes RM, Lotke PA. Determining femoral rotational alignment in total knee arthroplasty: Reliability of techniques. J Arthroplasty 2001;16(3):301-5.

Lonner JH, Siliski JM, Scott RD. Prodromes of failure in total knee arthroplasty. J Arthroplasty 1999;14(4):488-92.

Mantas JP, Bloebaum RD, Skedros JG, Hofmann AA. Implications of reference axes used for rotational alignment of the femoral component in primary and revision knee arthroplasty. J Arthroplasty 1992;7(4):531-5.

Nagamine R, Miura H, Bravo CV, Urabe K, Matsuda S, Miyanishi K, Hirata G, Iwamoto Y. Anatomic variations should be considered in total knee arthroplasty. J Orthop Sci 2000;5(3):232-7

Nagamine R, Miura H, Inoue Y, Urabe K, Matsuda S, Okamoto Y, Nishizawa M, Iwamoto Y. Reliability of the anteroposterior axis and the posterior condylar axis for determining rotational alignment of the femoral component in total knee arthroplasty. J Orthop Sci 1998;3(4):194-8.

Olcott CW, Scott RD. A comparison of 4 intraoperative methods to determine femoral component rotation during total knee arthroplasty. J Arthroplasty 2000;15(1):22-6.

Olcott CW, Scott RD. The Ranawat Award. Femoral component rotation during total knee arthroplasty. Clin Orthop 1999;(367):39-42.

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

Scuderi GR, Insall JN, Scott NW. Patellofemoral Pain After Total Knee Arthroplasty. J Am Acad Orthop Surg 1994 Oct;2(5):239-246

Stiehl JB, Abbott BD.Morphology of the transepicondylar axis and its application in primary and revision total knee arthroplasty. J Arthroplasty 1995;10(6):785-9.

Stiehl JB, Cherveny PM. Femoral rotational alignment using the tibial shaft axis in total knee arthroplasty. Clin Orthop 1996;(331):47-55.

Stiehl JB, Dennis DA, Komistek RD, Crane HS. In vivo determination of condylar lift-off and screw-home in a mobile-bearing total knee. J Arthroplasty 1999;14(3):293-9.

Stiehl JB, Dennis DA, Komistek RD, Keblish PA. In vivo kinematic analysis of a mobile bearing total knee prosthesis. Clin Orthop 1997;(345):60-6.

Whiteside LA, Arima J. The anteroposterior axis for femoral rotational alignment in valgus total knee arthroplasty. Clin Orthop 1995 Dec;(321):168-72

Yamada K, Imaizumi T. Assessment of relative rotational alignment in total knee arthroplasty: usefulness of the modified Eckhoff method. J Orthop Sci 2000;5(2):100-3

Yoshino N, Takai S, Ohtsuki Y, Hirasawa Y. Computed tomography measurement of the surgical and clinical transepicondylar axis of the distal femur in osteoarthritic knees. J Arthroplasty 2001;16(4):493-7.

Legends

Figure 1. The transepicondylar axis (Insall) is identified after intraoperative identification of both lateral and medial femoral epicondyles. Potential errors are landmark inconsistencies, previous trauma, femoral rotation, and ability to digitally identify both medial and lateral epicondyles.

Figure 2. The antero-posterior femoral axis method (Whitesides's line) references femoral rotation perpendicular to that line, which places the component approximately parallel to the transepicondylar line. Potential errors are femoral rotation variables, previous trauma, or patello-femoral diseases that may hinder anatomical identification.

Figure 3. Referencing femoral rotation in 3-4° external rotation to the posterior condylar line leads to an component positioning that approximates to the transepicondylar line, but has a large angular range. This method is arbitrary, based on estimates with variable reference lines in possibly distorted condyles, particularly in valgus or varus deformities.

Figure 4. Referencing femoral rotation from the posterior condylar line leads to an internally mal-rotated component positioning with an average of 4-5° to the transepicondylar axis, which requires varus tibial resection and increased valgus femoral resection to achieve a balanced rectangular flexion tension gap. Internal rotation will also have negative impact to the patello-femoral articulation.

Figure 5. Referencing femoral rotation perpendicular to the tibial shaft axis and a balanced flexion tension gap (LCS method) leads to prospectively predictable alignment parallel to the transepicondylar axis (mean 0.3°).

Figure 6. Free moveable femoral resection guide is attached to an intra-medullary femoral rod.

Figure 7. Spacer block (perpendicular to the tibial shaft axis) is attached to the femoral component and sits flat on the tibial resection for flexion balance check and determination of femoral rotational alignment.

Figure 8. Tibial resection is perpendicular to the tibial shaft axis and femoral resection block parallel to the tibial resection.

Figure 9. Spacer block determines rotational alignment of the femoral resection block with a balanced rectangular flexion tension gap setting the guide parallel to the tibial shaft axis.

Figure 10. Femoral component alignment parallel to transepicondylar axis ensures optimum patello-femoral tracking.

Figure 11. Transversal CT scans are a practical method for accurate determination of femoral component rotational positioning in TKA best referenced to the transepicondylar axis. Example of a well-aligned femoral component parallel to the TEA.

Figure 12. Graph showing normal distribution of femoral component rotational alignment in the subset group. Mean rotation of the femoral component was parallel (0.3°) to the transepicondylar axis, ranging from 6° internal to 5° external rotation.

Figure 13. Perfect patello-femoral tracking can be expected when the femoral component is rotationally aligned parallel to the TEA.